4th LOI : detector

F. Grancagnolo
INFN - Lecce

TILC09 - April 17, 2009 - Tsukuba

The Collaboration

140 collaborators
33 institutions
15 countries

LOI guidelines

- Detector overall philosophy
- Sub-detectors technical discussion
  - Integration issues with machine
  - Shielding
  - Push-pull ability
- Detector optimization
  - Support structures and dead zones
- Alternative technological options
- Preliminary cost estimate
- Evaluation of physics performance on benchmark processes
- Calibration and alignment schemes
- Sensitivity to beam background
- Energy coverage up to 1 TeV
- Structure of proponent group
- Resources needed and time evolution
- Plans for R&D

Detector overall philosophy

- **Detector Complementariness**
- **Particle identification**
- **Subsystems Orthogonality**
- **Subsystems Self-sufficiency**
- **Subsystems Hermeticity**
- **Detector Lightness**

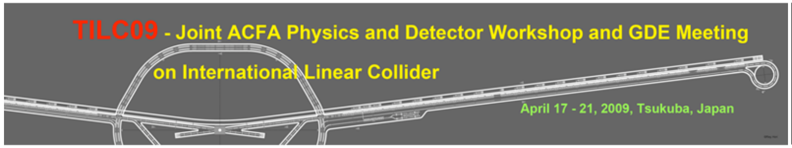
Detector overall philosophy

- **Detector Complementariness**

  To minimize the risk of bias for new discoveries and to reduce the systematic error contribution to precise combined measurements.
  The choice of one IR and two push-pull detectors makes sense only if the two detectors are complementary in technologies and use different methodologies:

  PFA calorimetry - multiple read-out compensating calorimetry
  solid state tracker - gas tracking device
  gas TPC - cluster timing drift chamber

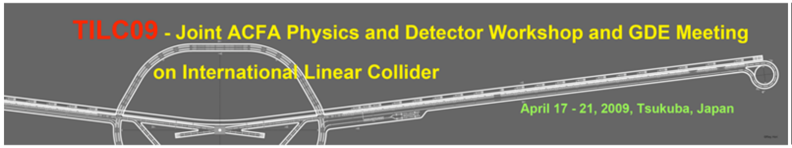
- **Particle identification**
- **Subsystems Orthogonality**
- **Subsystems Self-sufficiency**
- **Subsystems Hermeticity**
- **Detector Lightness**



Detector overall philosophy

- Detector Complementariness
- **Particle identification**

  Critical to all physics at a linear collider, for particles at both high (dual readout calorimeter) and low (cluster counting drift chamber) momenta.
  As many standard model partons as possible must be identified by direct measurements in independent detectors
- Subsystems Orthogonality
- Subsystems Self-sufficiency
- Subsystems Hermeticity
- Detector Lightness



Detector overall philosophy

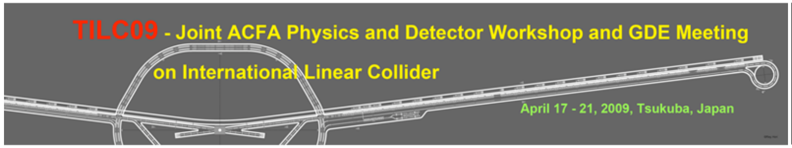
- **Detector Complementariness**
- **Particle identification**
- **Subsystems Orthogonality**

  Calorimeter response should be independent from tracking performance and tracking should not depend on calorimeter or vertex measurements. Possible cross-correlations must be avoided in the measurements of independent event parameters. Hard to achieve in jets.
- **Subsystems Self-sufficiency**
- **Subsystems Hermeticity**
- **Detector Lightness**

Detector overall philosophy

- Detector Complementariness
- Particle identification
- Subsystems Orthogonality
- **Subsystems Self-sufficiency**

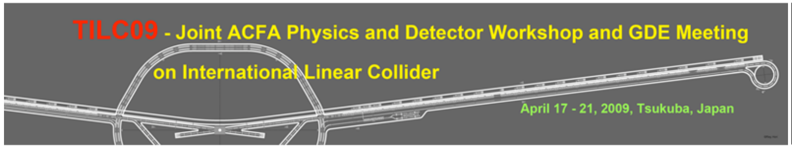
  Subsystems must not need auxiliary or ancillary detectors like: tail catchers or pre-shower detectors for a too shallow or not granular enough calorimeter; silicon blankets or additional tracking systems to assist pattern recognition, to complement momentum resolution or to extrapolate through dead volumes; end-cap tracking devices to re-measure tracks after too massive end-plates; multiple different technologies for lack of measurement redundancy.
- Subsystems Hermeticity
- Detector Lightness



Detector overall philosophy

- Detector Complementariness
- Particle identification
- Subsystems Orthogonality
- Subsystems Self-sufficiency
- **Subsystems Hermeticity**

  No dead area. All available volume must be used for measurements.
  Minimal mechanical clearance, sensors and electronics between subsystems.
  Supports are kept out of the active volume or, as for the had. calo. in the back.
  Ultralight structure and low power front-end electronics for tracking to avoid cooling and heavy supports.
- Detector Lightness



Detector overall philosophy

- **Detector Complementariness**
- **Particle identification**
- **Subsystems Orthogonality**
- **Subsystems Self-sufficiency**
- **Subsystems Hermeticity**
- **Detector Lightness**

Given the constraints due the push-pull operations (stray B-field outside detector, rolling) cost of the return iron yoke invested in a system of magnets to return B. Saved 14 Kton (>80%) at same cost. Muon spectrometer in air ($\Delta p_{\perp}/p_{\perp} \sim$ few ‰). Some additional shielding may be needed (see LOI).

integration

1. **Crane requirement** is set by the mass of the **inner solenoid**, about 220 Ton (based on the CMS solenoid). We expect to improve on this since the CMS solenoid was designed to support the hadronic barrel calorimeter, whereas on 4th the calorimeter will be supported externally.
The **outer solenoid** will be built in sections. The calorimeter modules will transported in small units.
Boron carbide radiation **shielding blocks**, will be designed to match the crane capacity set by the solenoid.

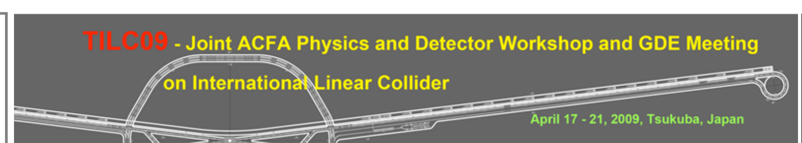
2. **Space underground** is not determined yet, but **30 X 50 m^2** and **25 m** high is ample space.

3. **Shaft diameter** (vertical access) can be 15 m (**18 m** with clearances).

4. **On-beamline opening procedures** are: (i) move Lumi/Beam-Cals out axially, (ii) move 4th end-coils out 3m, (iii) move muon spectrometer end-cap out axially, (iv) move calorimeter end cap out axially. At this point, the tracker end cap with electronics is accessible, the FF support is in place and accessible. Then, (v) the tracking chamber can be push-pulled to the other end, and the vertex chamber is made accessible in this position. **All subsystem components are held on rails**.

5. **Off-beamline opening procedures** are similar to on-beamline, but easier.

6. **Fire safety**: 4th has a flammable 10% isobutane in helium gas mixture in the tracking volume. If necessary, we could operate at 5% level, just below the flammable limit.



shielding

The only drawback of an iron-free detector is insufficient self-shielding.

The radiation requirements indicate that 2.5 meters of concrete shielding is sufficient (see T. Sanami).

Calculations show that, for 4th, beam loss at Lumi Cal is the worst.

However, the dose rate becomes less than 0.014 mSv/hr/kW for shielding consisting of the dual-readout calorimeters, the inner and outer solenoids, plus a concrete shield with boron carbide liner (1.0 m thick forthe barrel region, 1.5 m thick for the endcap region), plus a 1.2 m stainless steel shield near the pacman position (ID=1.6 m, OD=4.m).

A final design that will optimize the mass and cost trade-offs between more calorimeter depth and more shielding will be addressed in the post-LoI period to balance the costs and the push-pull time penalty of restacking shielding blocks and the IR floor space penalty to store these blocks.

push-pull ability

The 4th Concept detector is modular and light-weight and we do not see any show-stoppers in push-pull.

The **FF lenses** are carried by the detector, and therefore the compensation of the movement of the beam-delivery system elements are under control for 4th. The **final quadrupoles** will be supported by the detector itself to greatly decrease the incoherent beam motion due to ground motion and vibration, and for near-IP control of the final beam aim and focus.

QuickTime™ and a decompressor are needed to see this picture.

Active tuning, mechanical and electromagnetic correction coils, would allow for a quick restoration of luminosity.

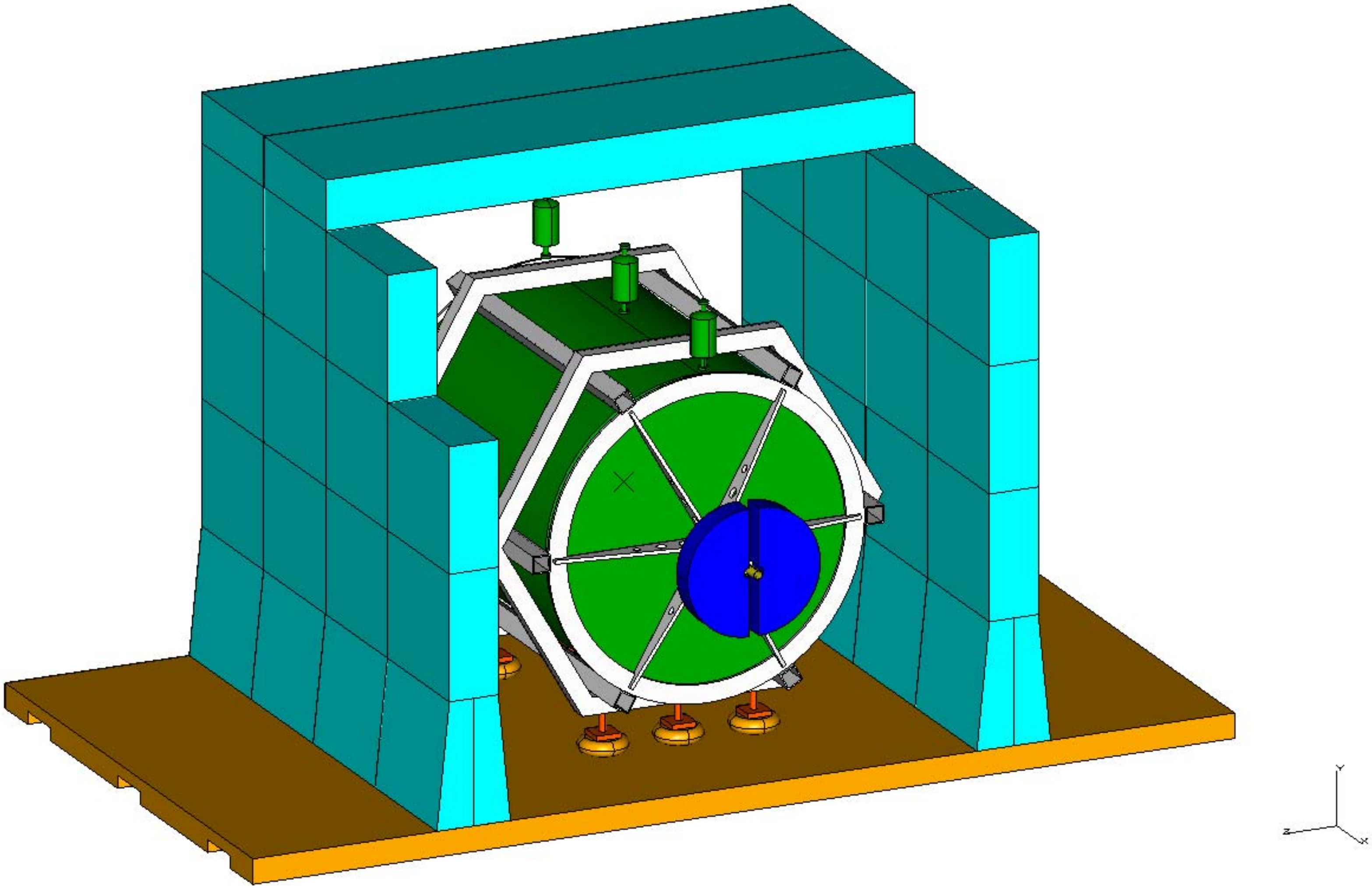
All power, water, cryogenics and data cables are attached to the detector so that easy motion is possible without reconnection. The signal connections are few.

The cryogenic connections move with the detector.

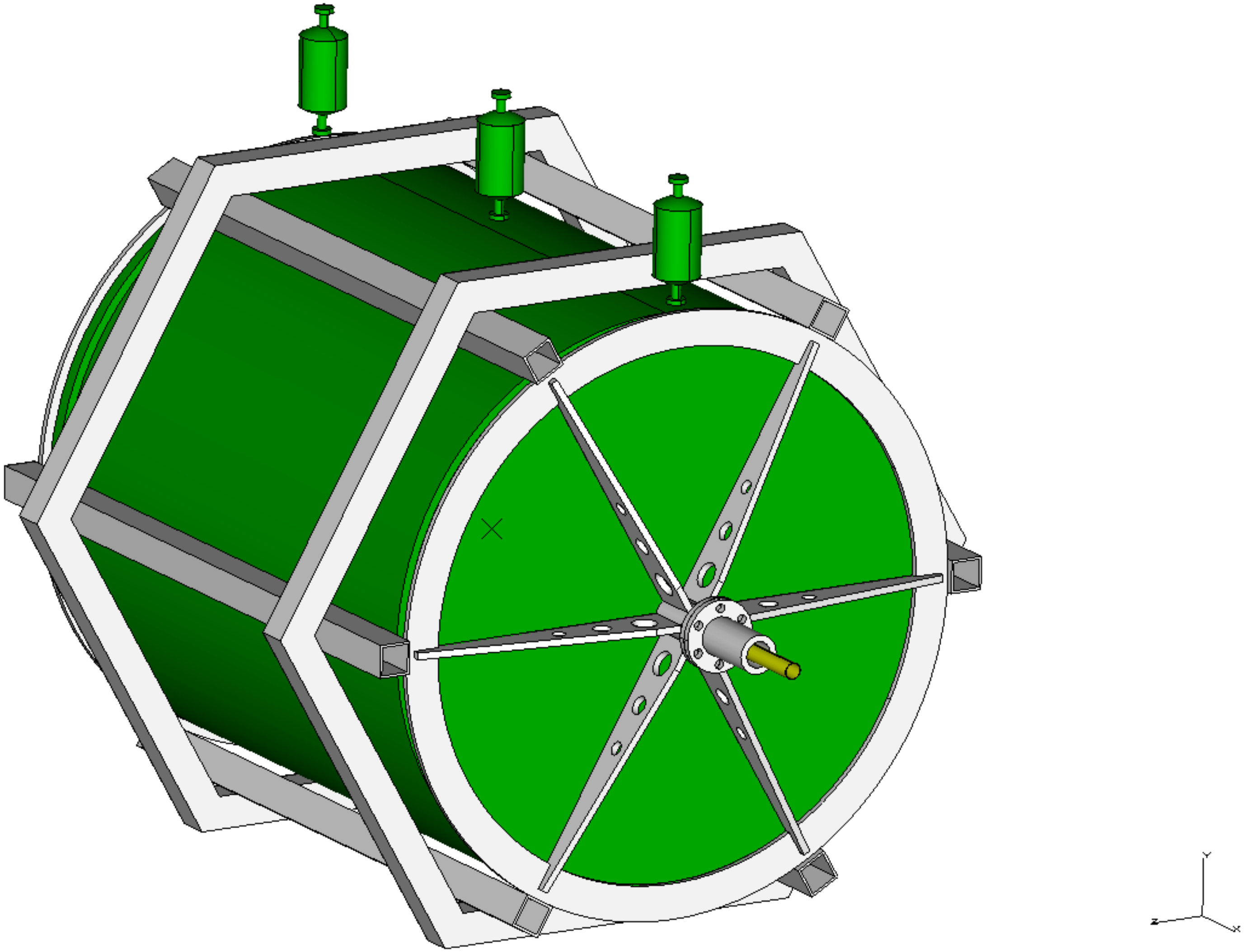
QuickTime™ and a decompressor are needed to see this picture.

QuickTime™ and a decompressor are needed to see this picture.

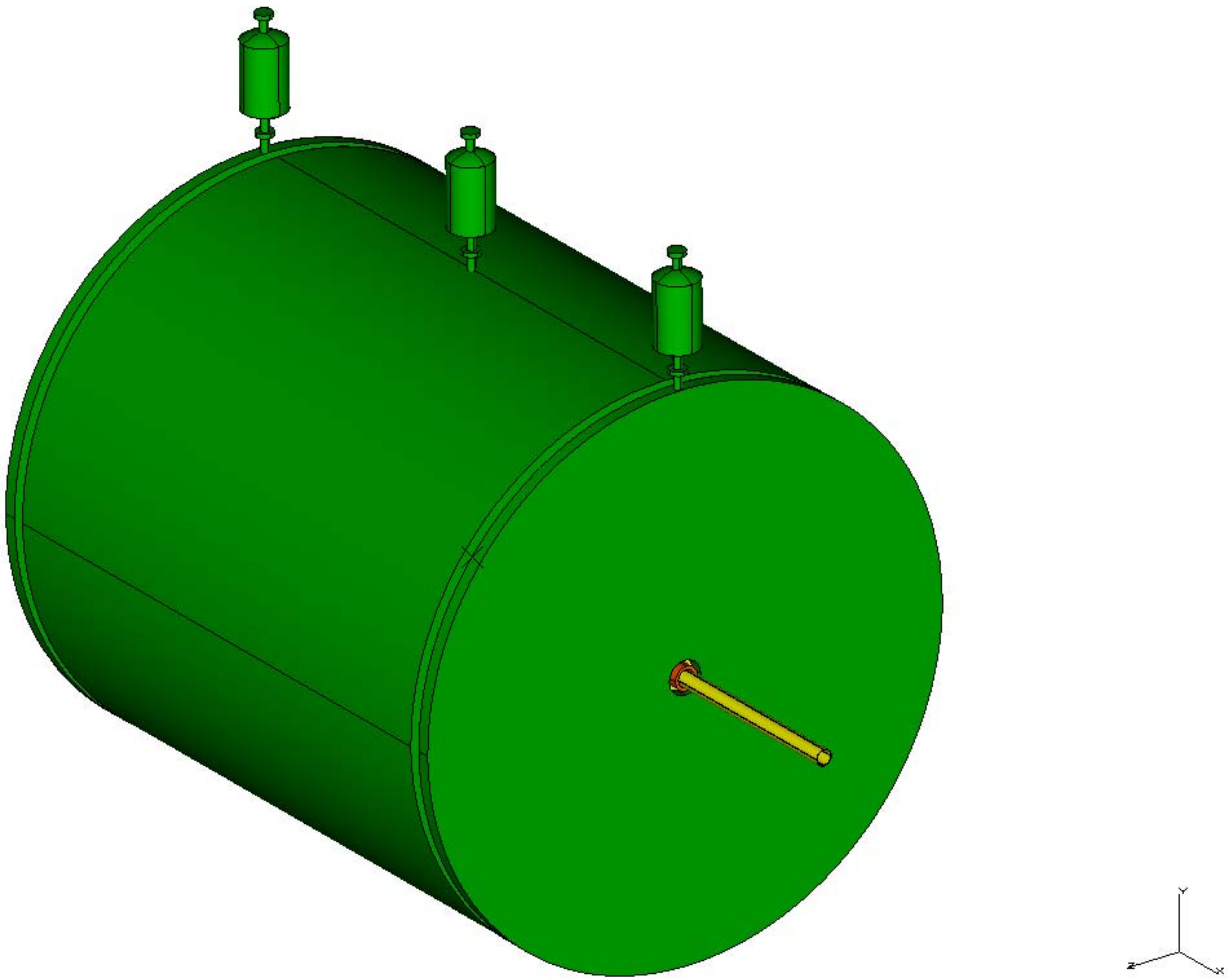
Remove shielding



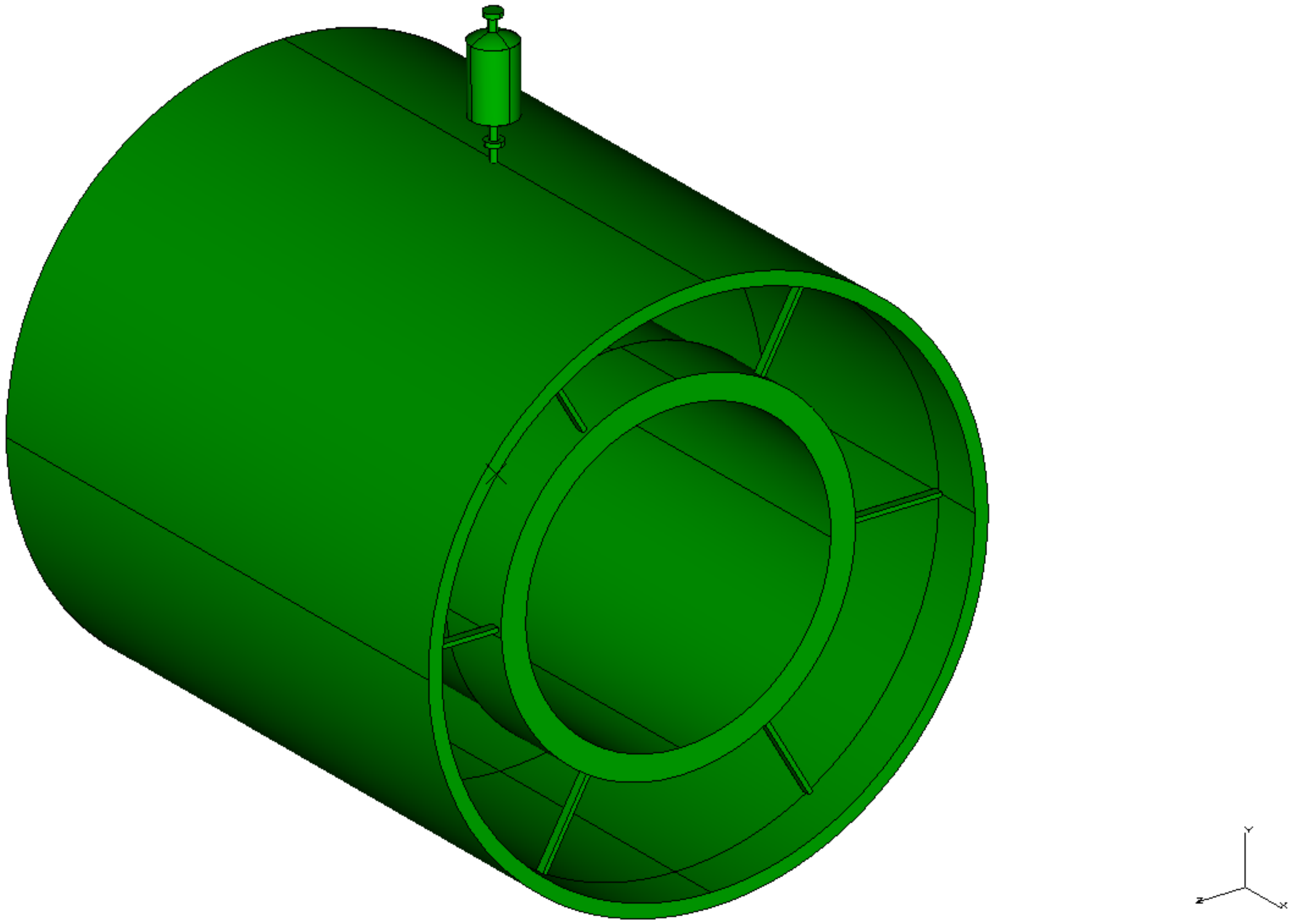
Remove frame



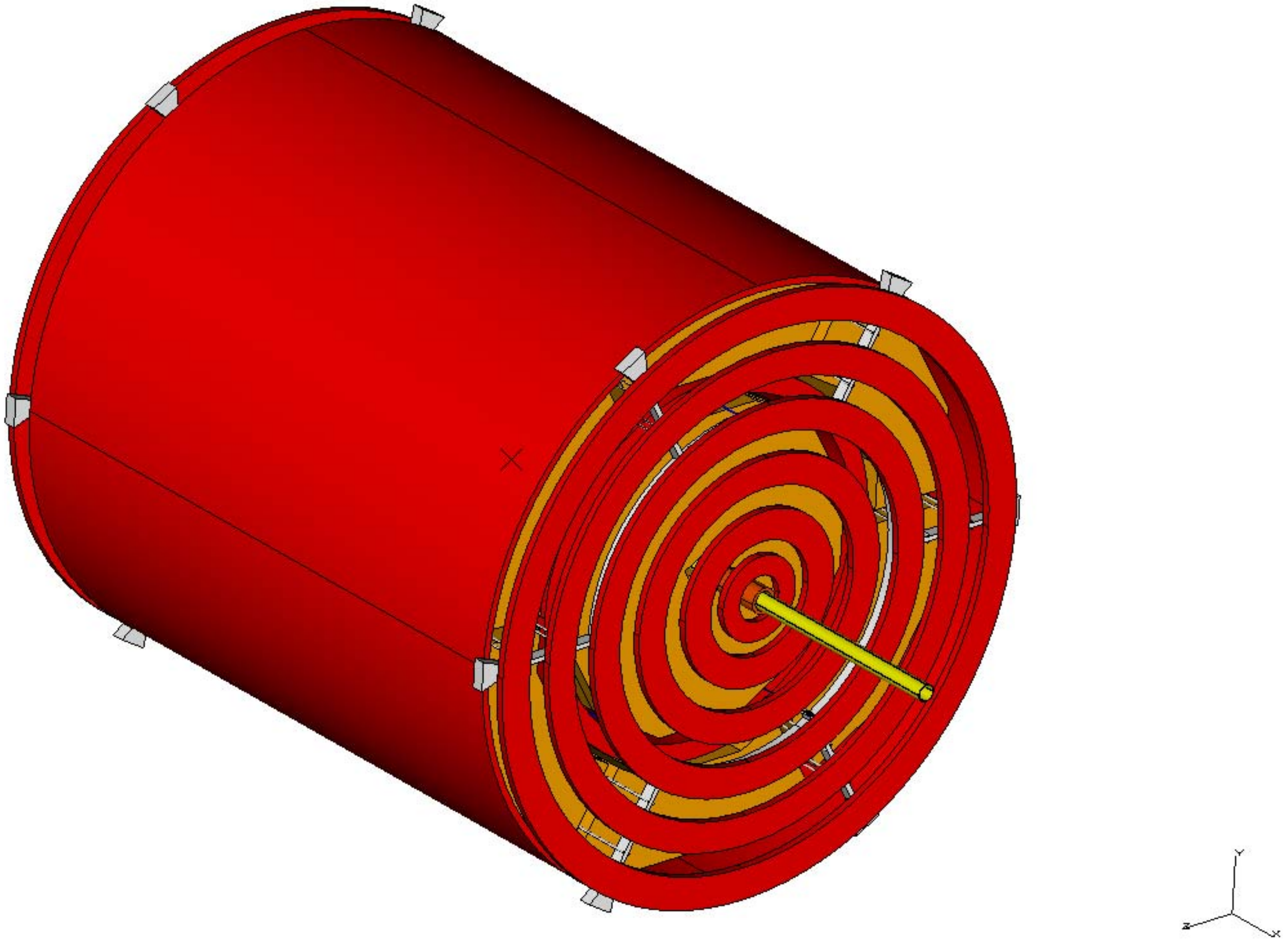
Removed frame



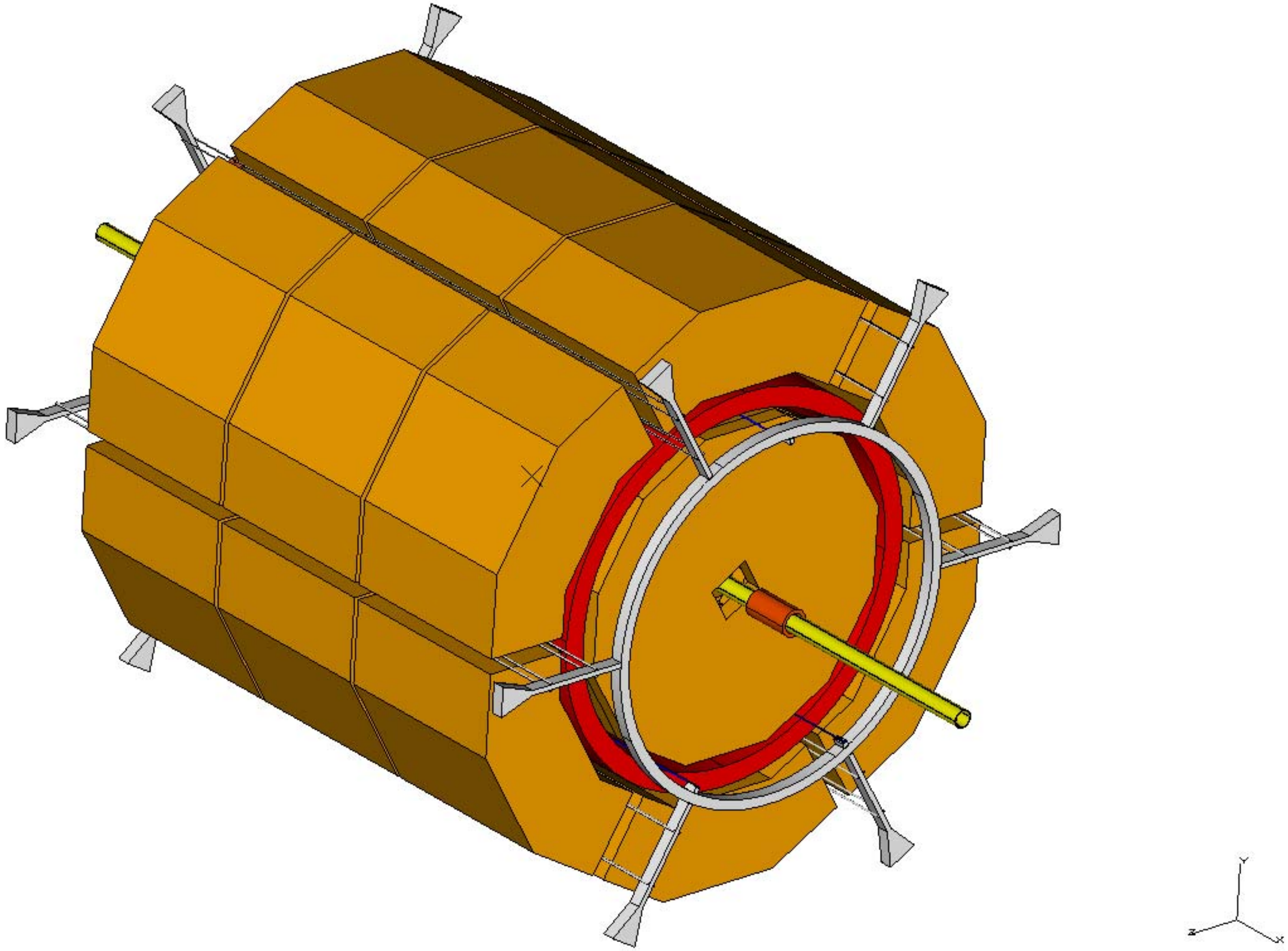
Removed end cryostats



Removed central cryostat

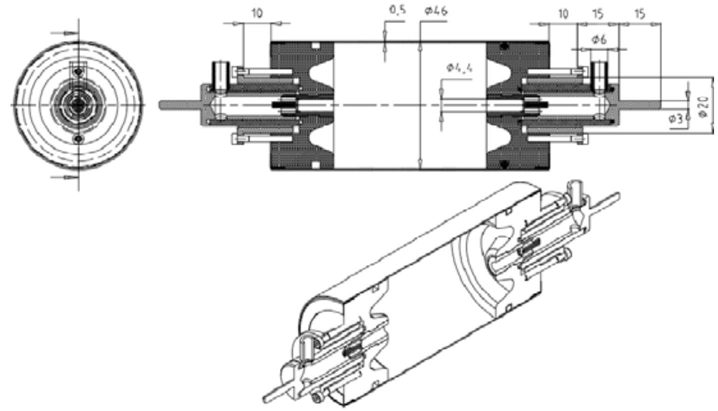


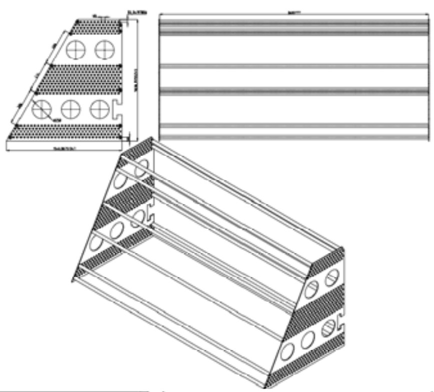
Removed outer solenoid



Muon Spectrometer

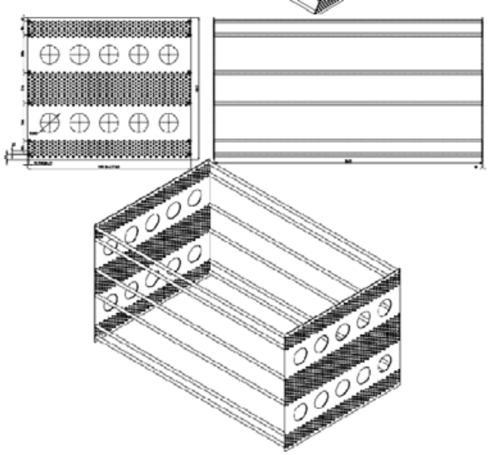
The basic building block is a **4.6 cm drift tube** using the **same He gas mixture** and the **same front end electronics** as **CluCou**.





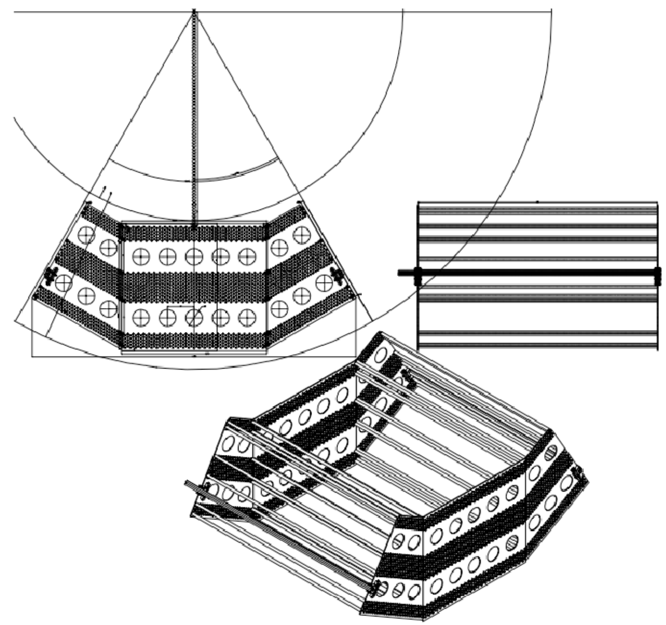
Precision positioning plates are used to align the tubes.

Only two different muduli, 4 m long, 460 and 1100 tubes each, are necessary to build 1/6 of 1/3 of the whole barrel.

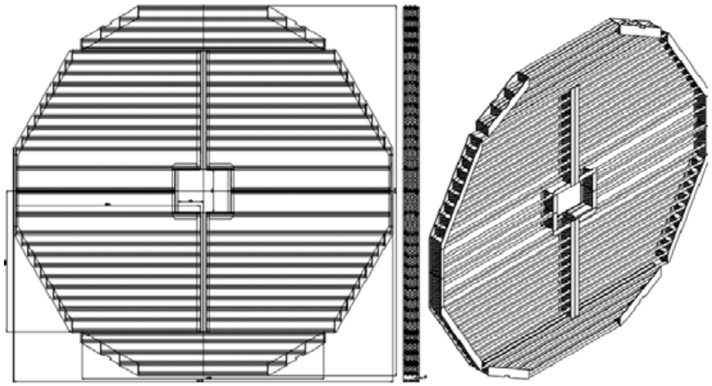


The three corresponding tubes along *z* are ganged together for a more precise *z*-coordinate measurement with current division.

20 layers of tubes radially.

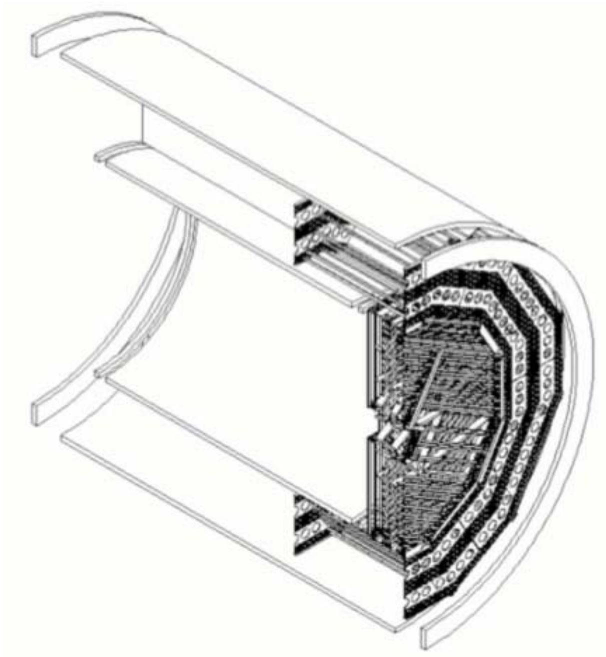


Muon Spectrometer

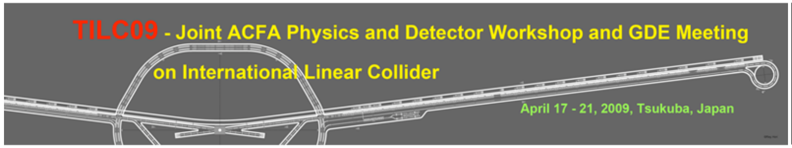


Each end cap plane is made of three basic moduli.
One end cap is made of three planes rotated by 120º.

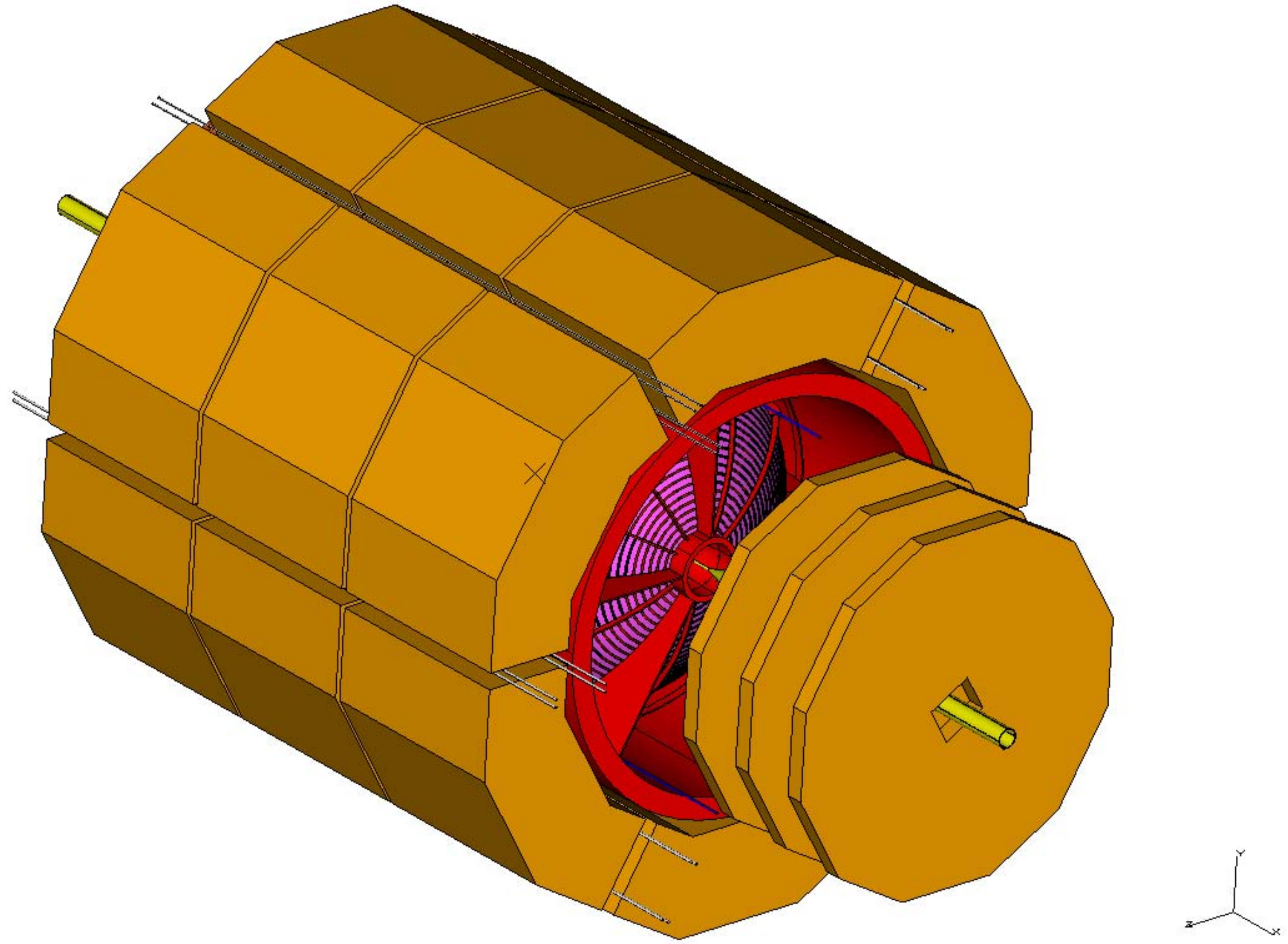
6 tubes per projection, 18 per end cap.



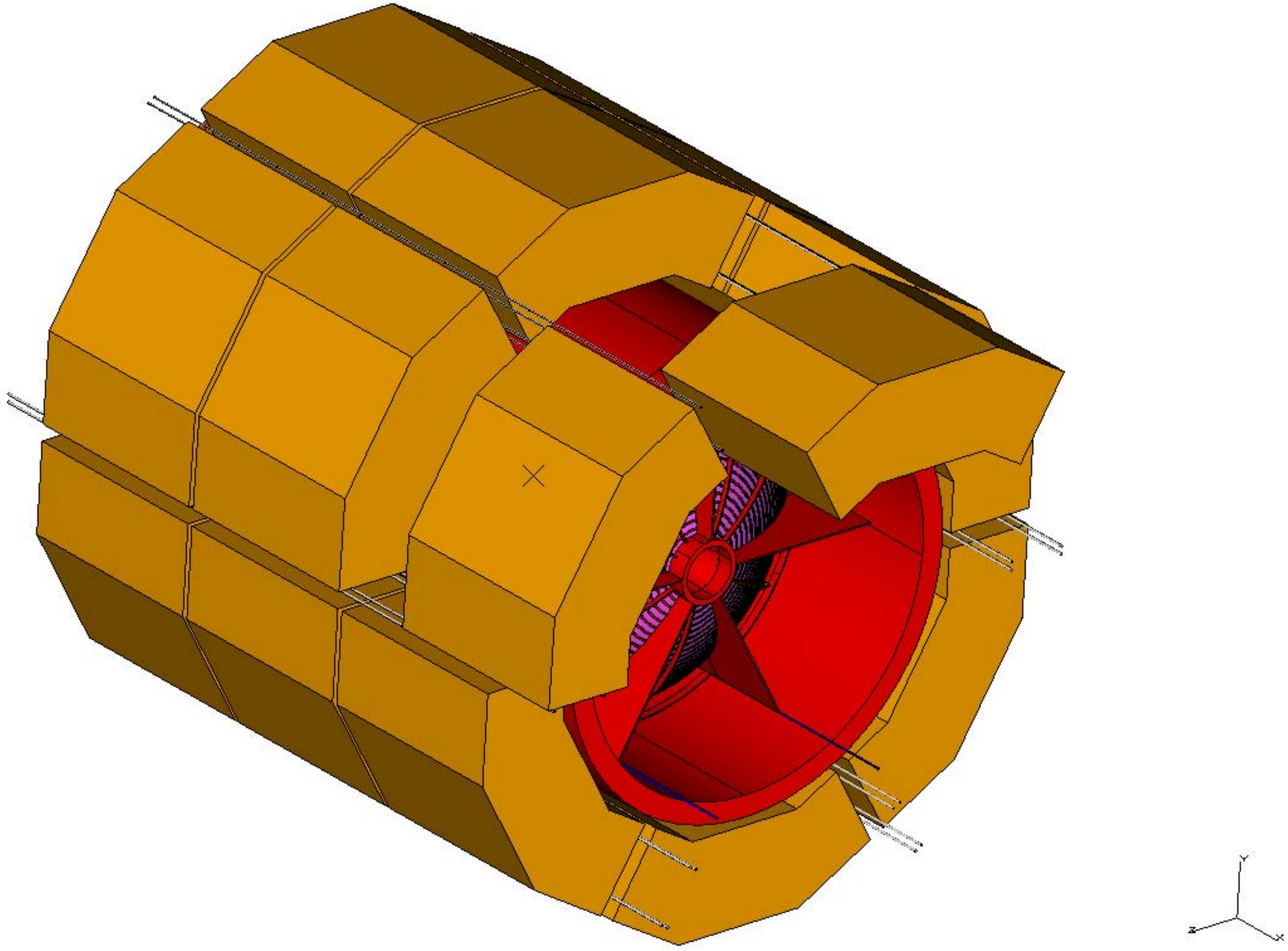
Total number of tubes: 45000.
Total number of electronics channels: 34000.



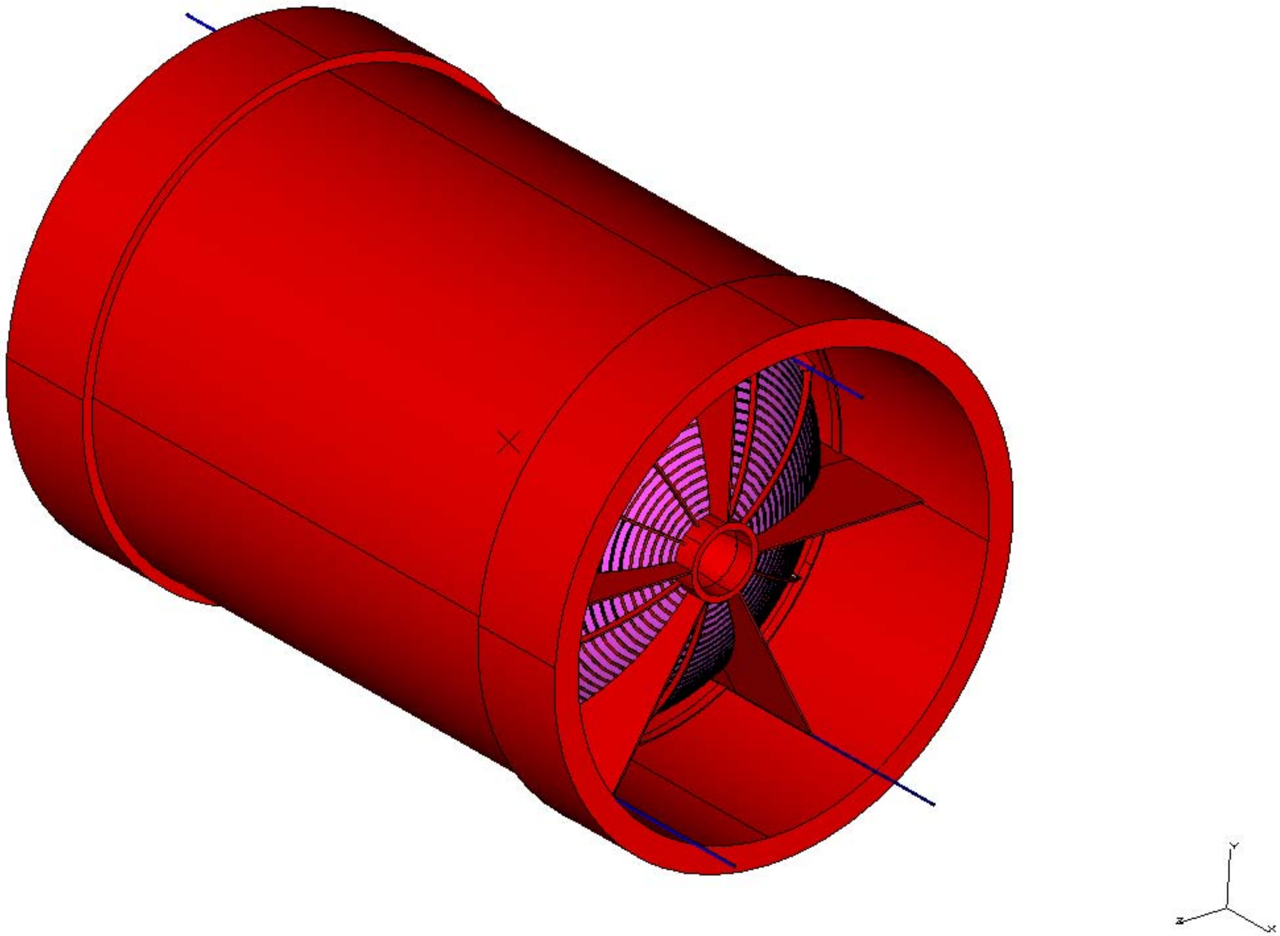
Remove muon end caps



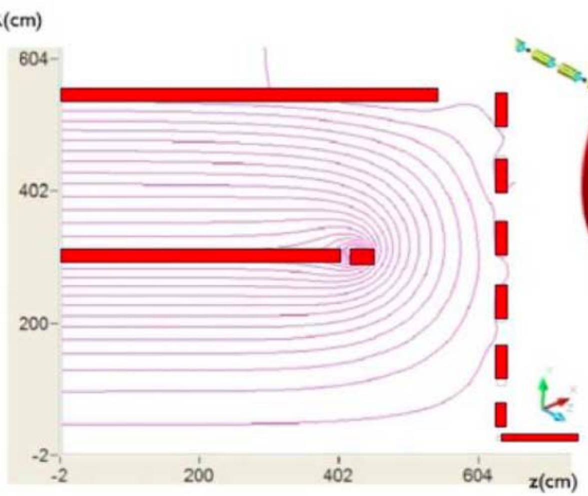
Remove muon barrel

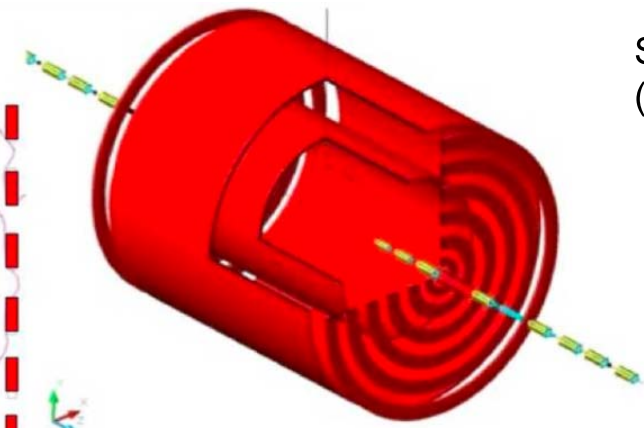


Removed muon spectrometer



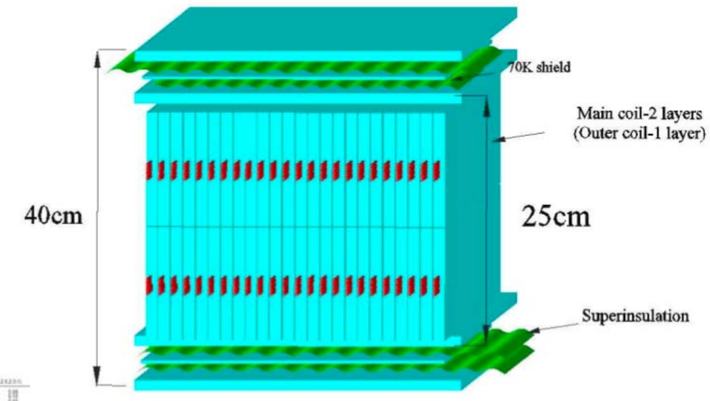
Magnet System

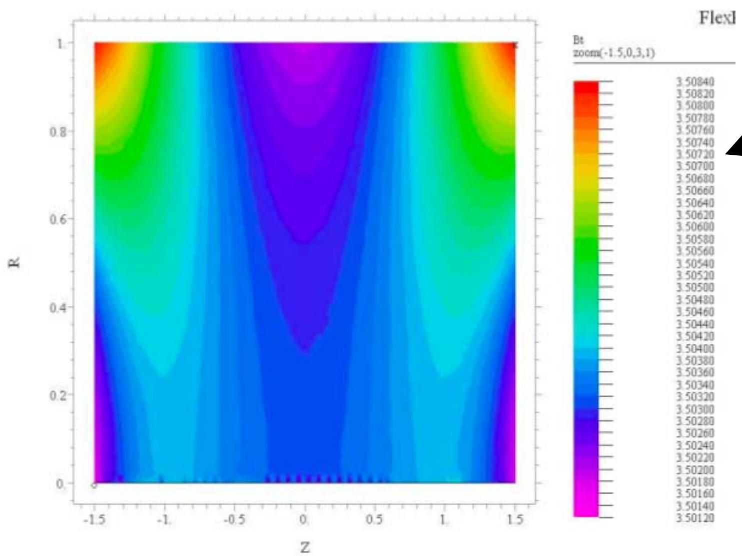




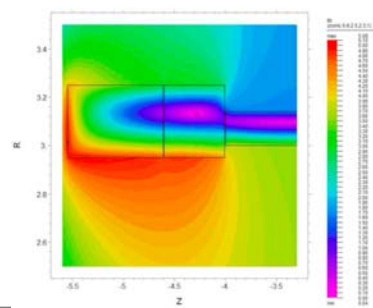
See "Solenoid Design" by A. Mikhailichenko (LOI - Appendix A)

We think we can use the CMS-type conductor with a safety margin of 2 for the inner and outer solenoids.





B uniformity < $2X10^{-3}$ in tracking volume

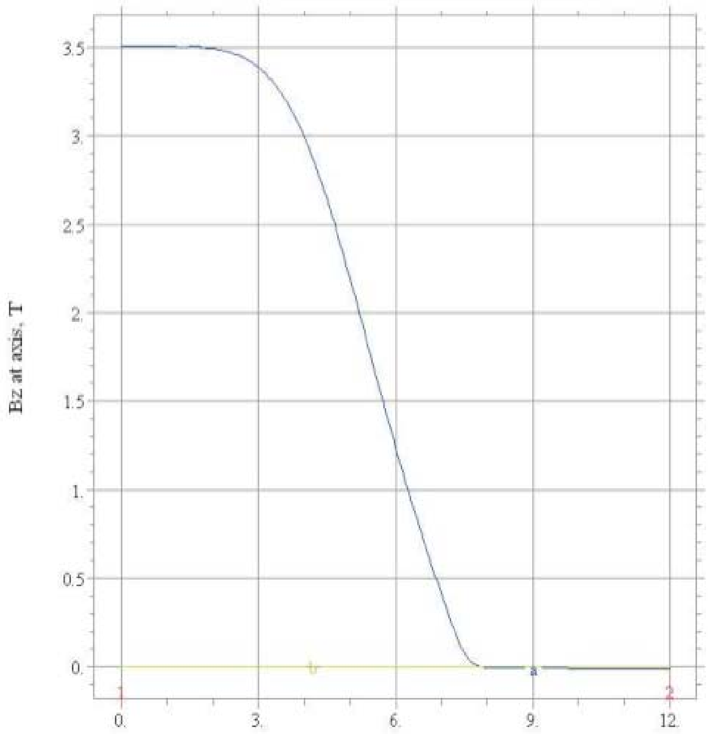


A larger size Helmholtz coil may be needed to reduce the current.

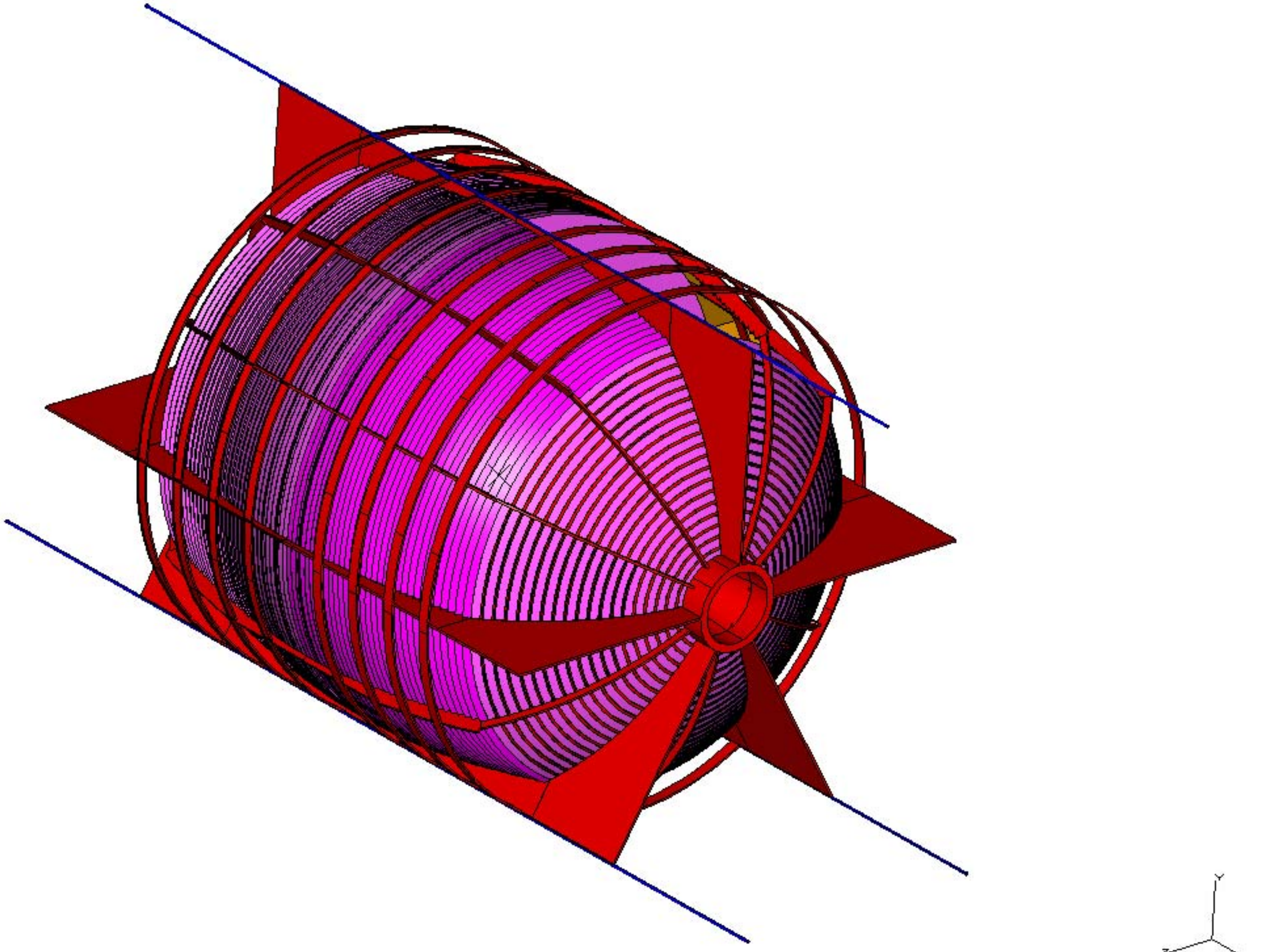
Magnet System

Advantages of a dual magnetic system

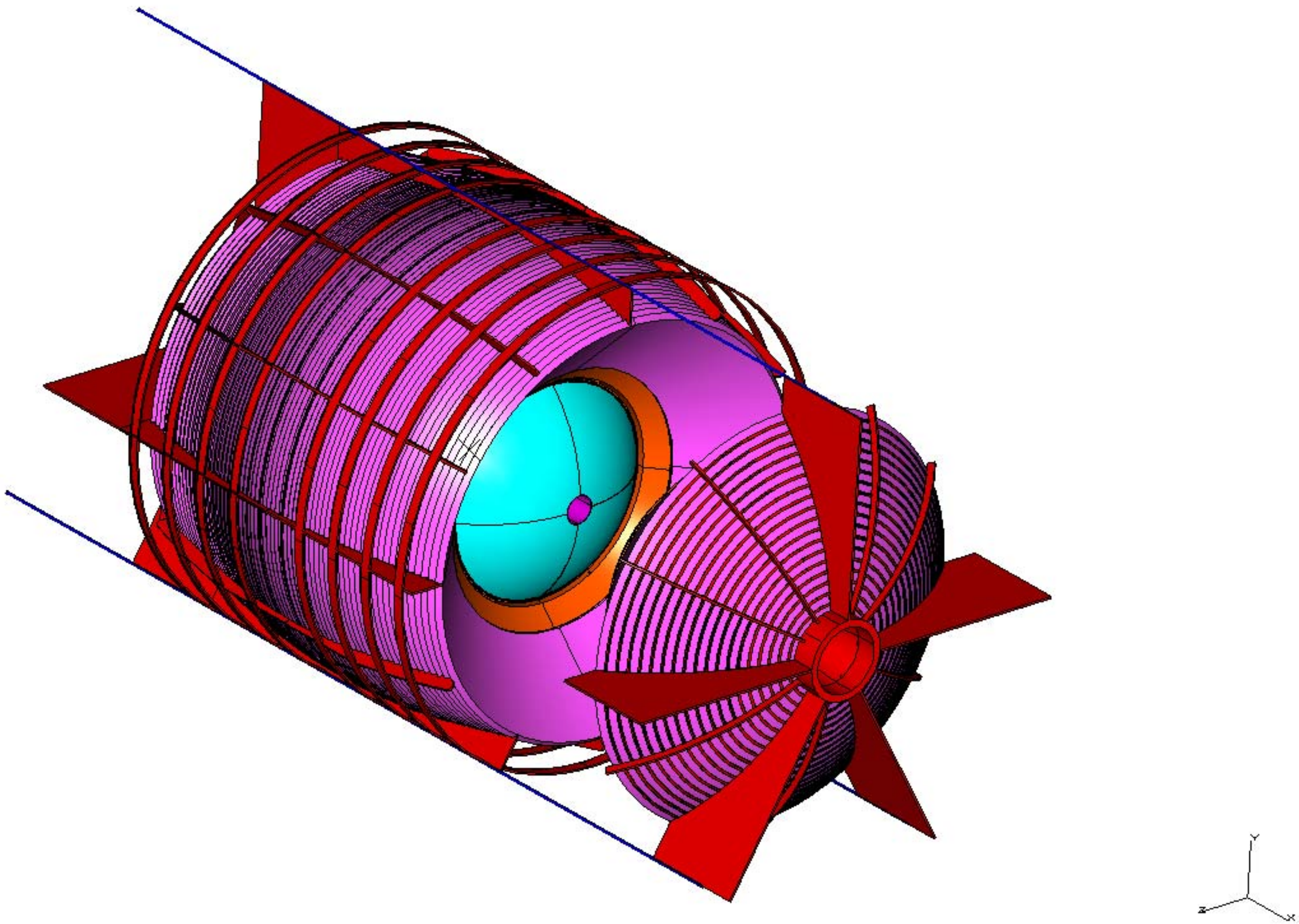
- **avoids 14 kTon** of flux return **iron** (cost and weight)
- **avoids** huge **forces on iron** at switch on/off (support)
- **allows** for a **muon spectrometer in air** (two orders of magnitude better momentum resolution)
- **allows** for a **ZERO fringe field** outside of the magnet volume
- its open geometry **allows** for the **FF optics** to be placed **inside** the detector on the same support structure (stability against ground motion)
- its open geometry **allows** for an easier **survey and alignment** of internal subsystems
- **allows** to run at **any value of B**, from B= –3.5T to B= +3.5T, including 0T (study of asymm.)



Removed inner solenoid



Remove fiber/crystal end cap



Crystal Calorimeter

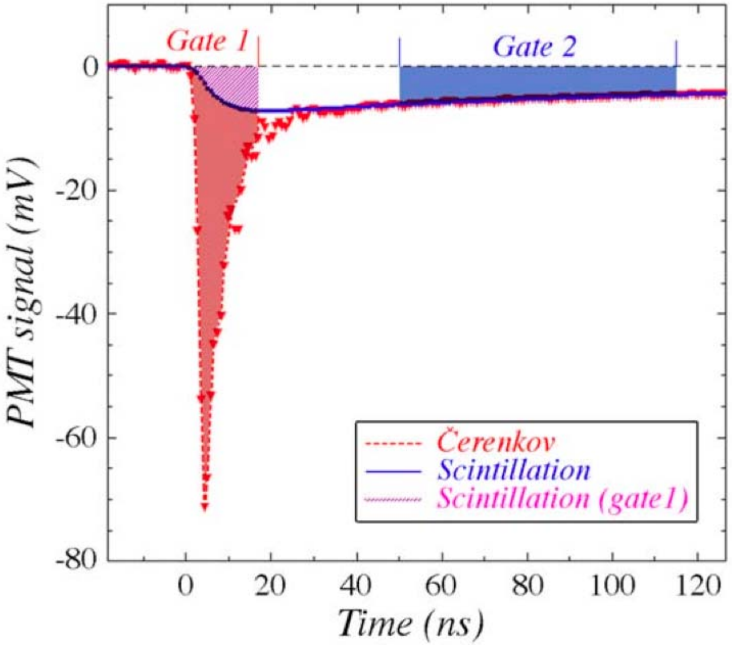
The physics motivation for placing **crystals** (we have chosen **BGO** for the beam tests and for their detailed simulations) upstream of the fiber calorimeter is to achieve optimum **electro-magnetic four-vector resolutions** on γ and *e* while maintaining, at the same time, the unprecedented **hadronic energy resolution** granted by the **fiber calorimeter**.
See next talk by Corrado Gatto on the very good reproducibility of the DREAM beam test data by the ILCroot simulations and the resulting excellent combined performances of the two calorimetric systems.

Cerenkov (black filter) and scintillation (yellow filter) oscilloscope signals from beam DREAM data in BGO.

Two separate readouts are not required. A single readout will accomplish dual-readout of BGO:

$$S = \int_{50ns}^{115ns} p.h.(t) \cdot dt$$

$$C = \int_{0}^{15ns} p.h.(t) \cdot dt - 0.2S$$



Crystal Calorimeter

BGO's are located just outside the tracking chamber and consists of **25 X_0** of **$(2cm)^2$** laterally segmented crystals (the benchmark processes have been simulated with $(1cm)^2$ crystals to study coarser granularities).

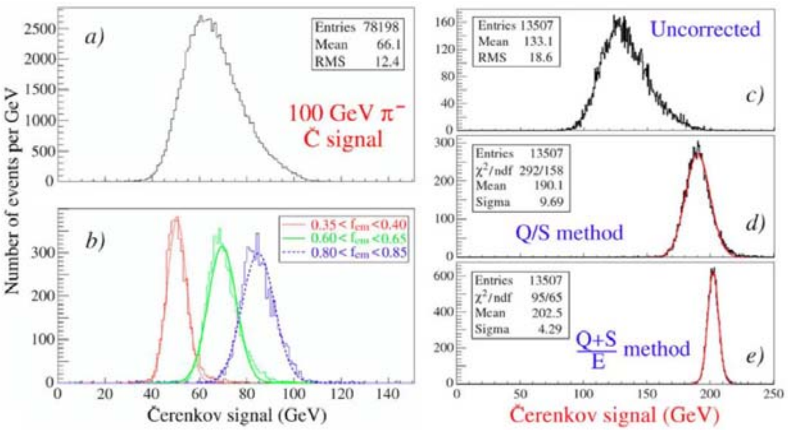
They are grouped in **2x2 arrays** to cover the surface of each single fiber calorimeter tower, for a total of about **96000 single crystals** (and readout channels).

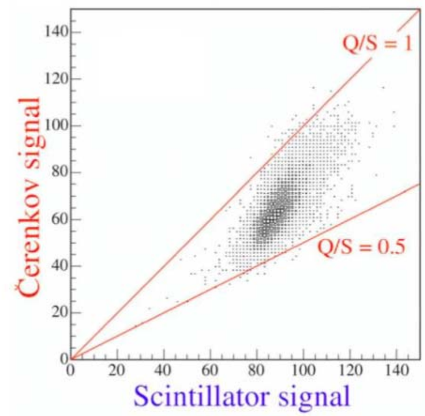
The photo-detectors and the relative electronics are placed on the front face of the crystals.

Given the high cost of the system (2/3 is BGO crystals, 1/3 is instrumented sensors), in the optimization procedure, we may decide to adopt a different type of crystal **(BSO**?) giving up some of the excellent resolution, but cutting the total cost by about a factor of 2 (50 M$).

Fiber Calorimeter

Based on the well established and copiously documented technique of **dual readout in fibers**. Deep understanding of the under laying physics processes proven by the detailed reproducibility of the beam test data in ILCroot.





$$Q = E\left[f_{em} + \frac{1}{(e/h)_Q}(1 - f_{em})\right]$$

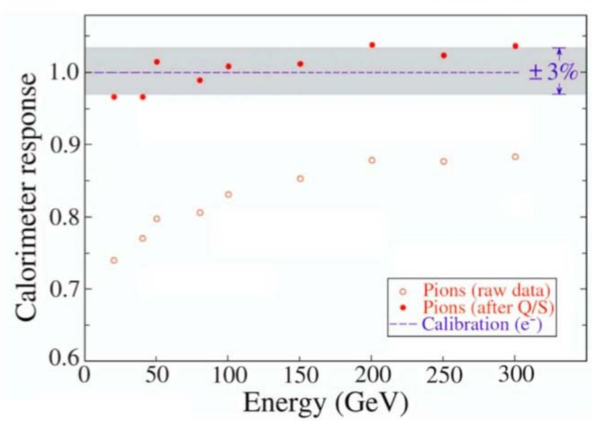
$$S = E\left[f_{em} + \frac{1}{(e/h)_S}(1 - f_{em})\right]$$

e.g. If $e/h = 1.3$ (S), 4.7 (Q)

$$\frac{Q}{S} = \frac{f_{em} + 0.21\,(1 - f_{em})}{f_{em} + 0.77\,(1 - f_{em})}$$

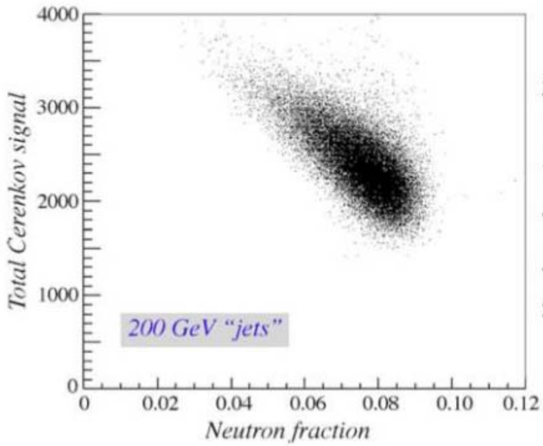
$$E = \frac{S - \chi Q}{1 - \chi}$$

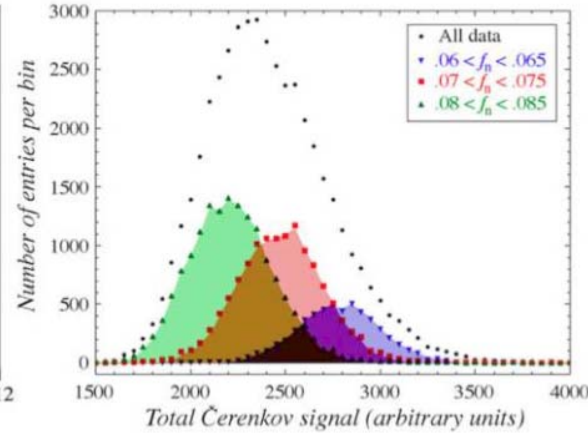
with $\chi = \frac{1 - (h/e)_S}{1 - (h/e)_Q} \sim 0.3$



Refer to C.Gatto (next talk) for performances of the dual readout approach for **hadronic showers** and for **jets**.

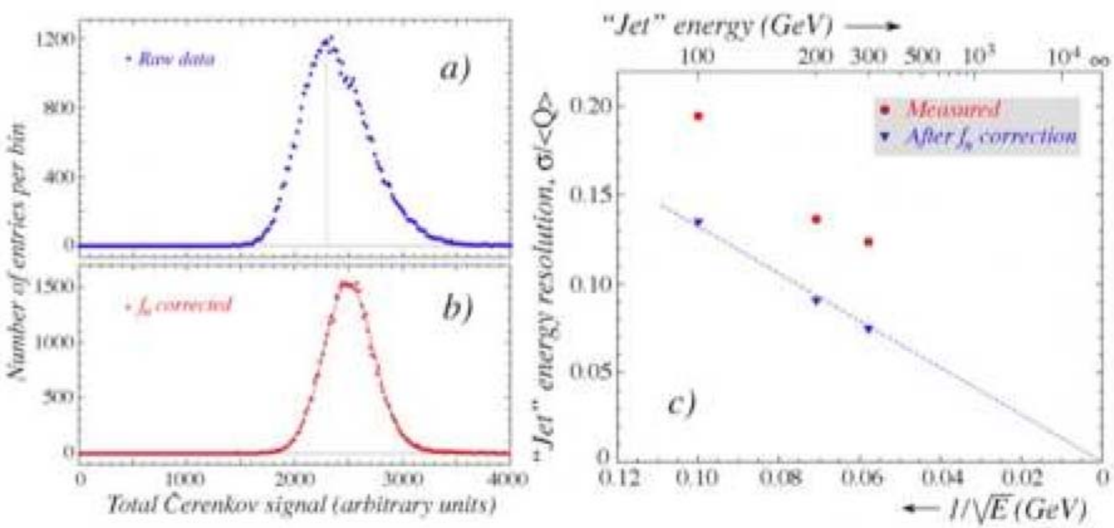
Fiber Calorimeter

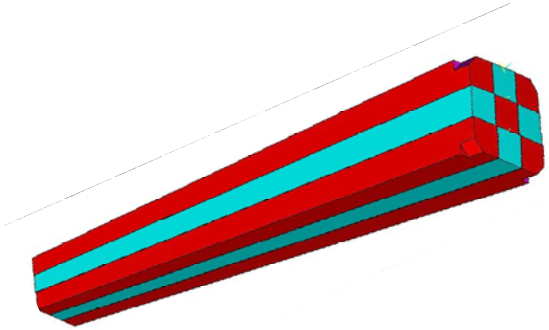




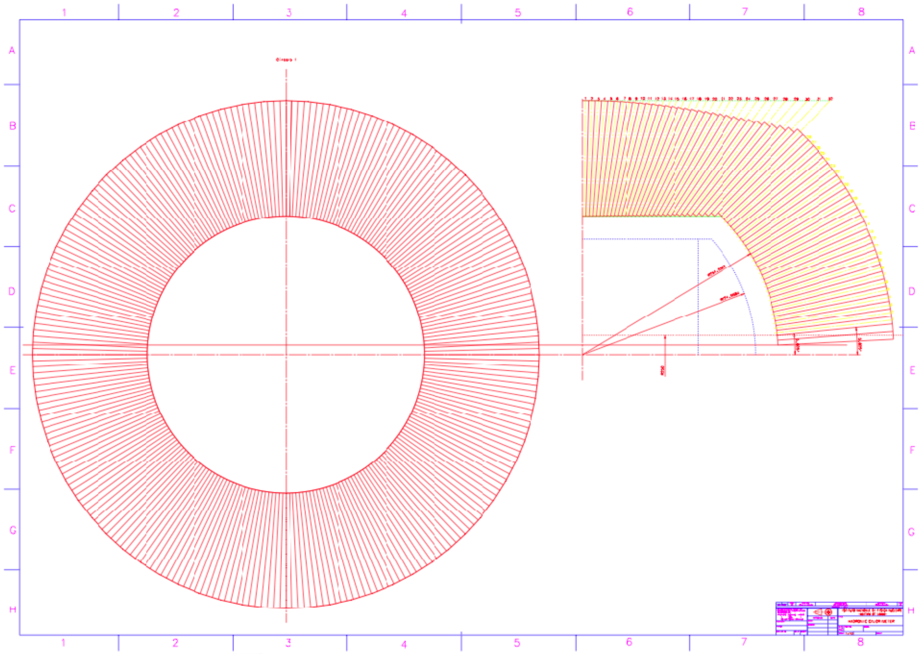
"triple readout"

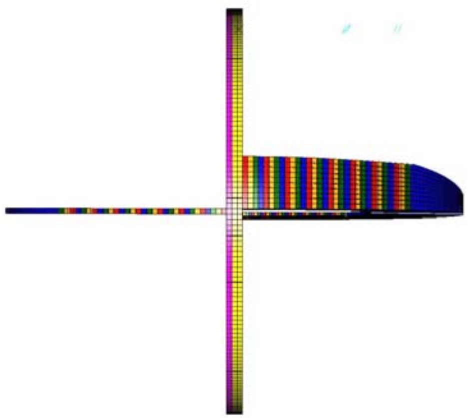
Measure the neutron content of a shower by the time-history of the scintillation signal since neutron velocity 🖫 0.05c and they fill a larger volume of the calorimeter

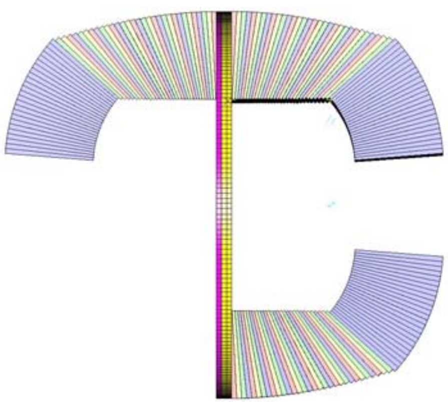




Fiber Calorimeter







The fiber calorimeter is a copper matrix loaded with 1 mm diameter alternating scintillating and clear (for Cerenkov light) fibers every 2 mm.

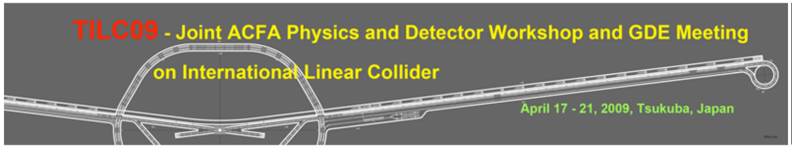
The basic building block is a tower, projective to the origin, with no longitudinal segmentation and covering approximately 1.4° both in θ and in φ.

Dimensions, at the inner face, range from about $(4.4\ cm)^2$ at θ = 90° up to about 6.3 x 4.4 cm^2 at θ = 45°. The outer face has a size twice the inner one. There are a total of about 1600 fibers per tower. Depth is 1.5 meters, corresponding to about 7.3 λ.

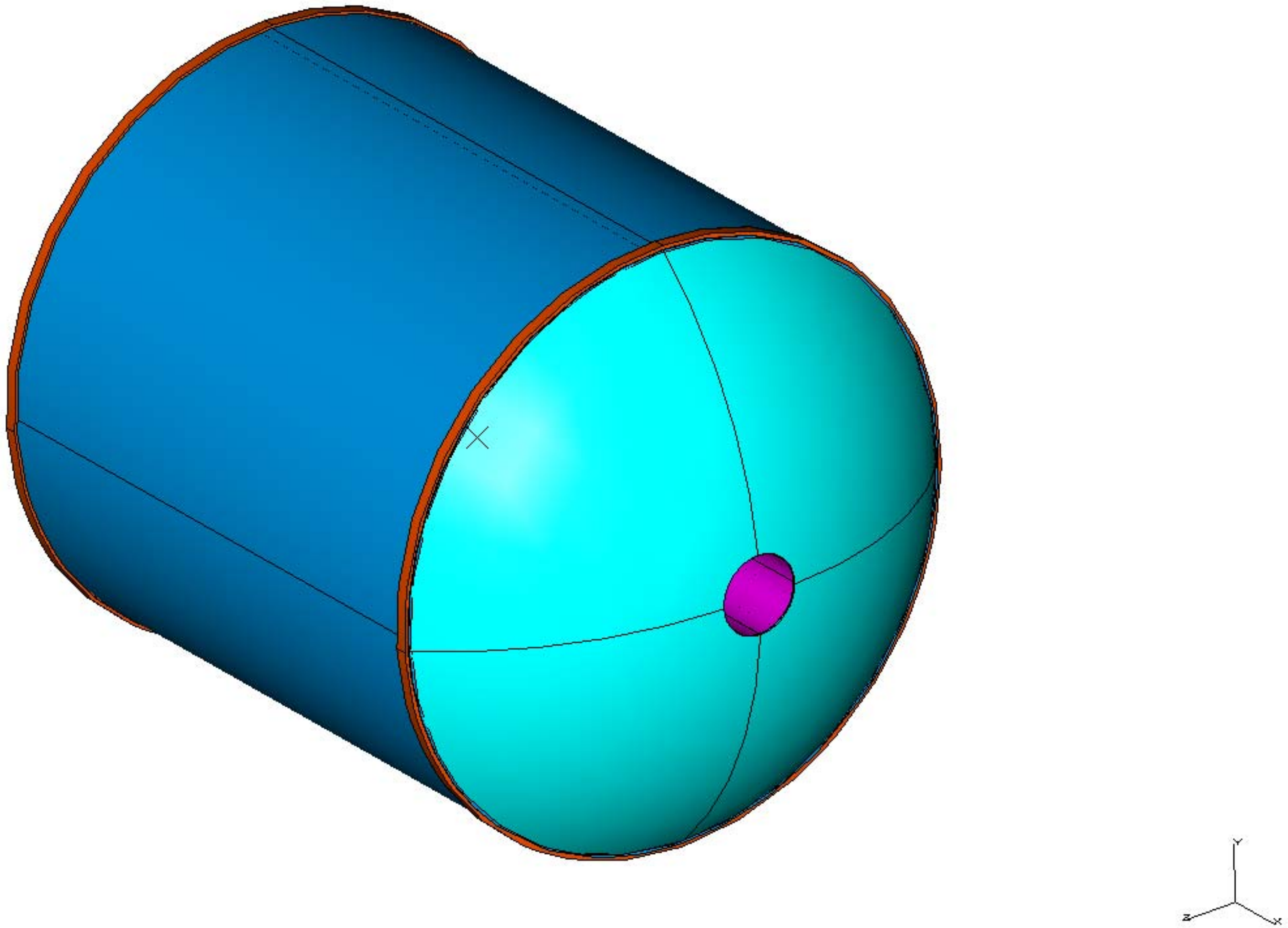
The towers on the endcap section cover a perfectly spherical surface which follows the spherical shape of the tracking chamber.

The angular coverage is hermetic down to $\theta \approx 2.8°$. The scintillating fibers and the Cerenkov fibers are grouped and readout in separate bunches at the back

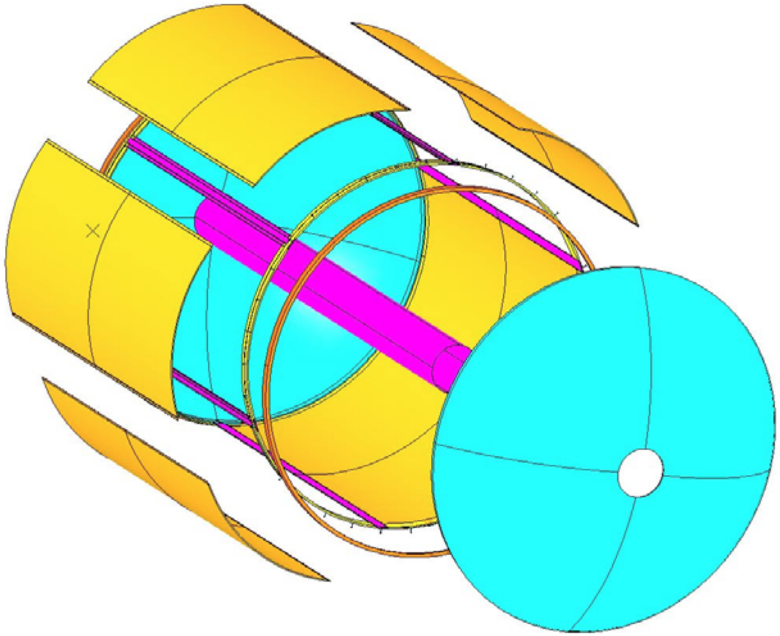
The total number of towers is 16384 in the barrel section and 7450 in the endcaps.



Removed calorimeters



Central Tracker



Central Tracker:

CluCou

- •all stereo, cluster timing drift chamber
- •light He based gas mixture
- •mechanical structure entirely C-fibre
- •max drift time contained in one BX
- •total tracking volume (inner wall, gas and wires) < 0.5% X_0
- •endplates (2.9% X_0), services (~5% X_0)

$$\frac{\Delta p_\perp}{p_\perp} = \frac{\sqrt{320}\cdot\sigma_{xy}}{0.3\cdot B\cdot\ell^2\cdot\sqrt{n}}\cdot p_\perp \oplus \frac{5.4\times10^{-2}}{B\cdot\ell}\sqrt{\frac{\ell}{X_0}}$$

(transverse length ℓ, σ_{xy} and X_0 in [m], B field in [T], momentum in [GeV/c]).

Required performance at ILC: $3.\times10^{-5} \oplus 1.\times10^{-3}$

Central Tracker

For a given $B\ell^2$, the requirements are met with

50 μm resolution and ~150 measurements in a 1.5 m radius (drift chamber)

or, with

10 μm resolution and a few (5) measurement planes (silicon tracker).

Drift chamber over silicon tracker advantages

Lower **multiple scattering** contribution for momenta up to several tens of GeV/c (**0.5% X_0** vs **5% X_0**).

Redundancy: insensitivity to local inefficiencies and to spurious hits, due to background or to shared occupancy in dense regions.

Alignment and its temporal **stability** (e.g., before and after a push-pull operation) with the rest of the detectors and with the interaction point in a time short enough to control systematics.

Continuous seeding in the active volume for track finding, not relying on the vertex detector or the calorimeter, thus capable of detecting and fitting **kinks and neutral vertices** with high efficiency (hard to accomplish in a few planes silicon tracker).

Central Tracker

Drift chamber over TPC advantages

Lower **multiple scattering** contribution for momenta up to several tens of GeV/c (**0.5% X_0** vs **4% X_0**) in barrel region and (**8% X_0** vs **15% X_0**) in the endplates, without inner and/or outer blankets

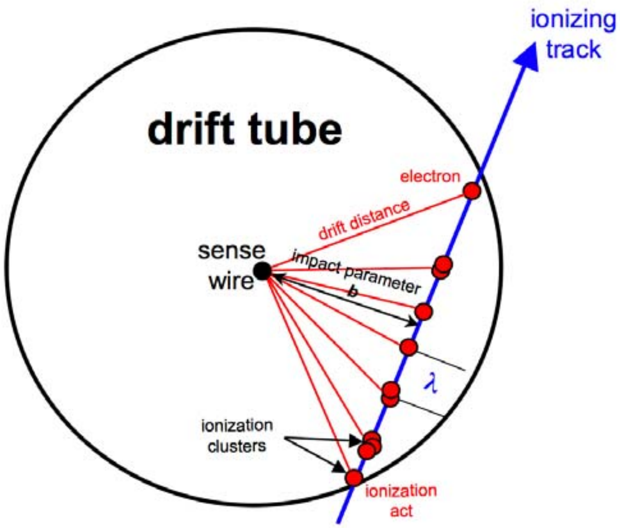
Single event per bunch crossing as opposed to the integration of at least **150 BX's**: **pattern recognition** more difficult and particularly severe because of the large integration of **backgrounds**.

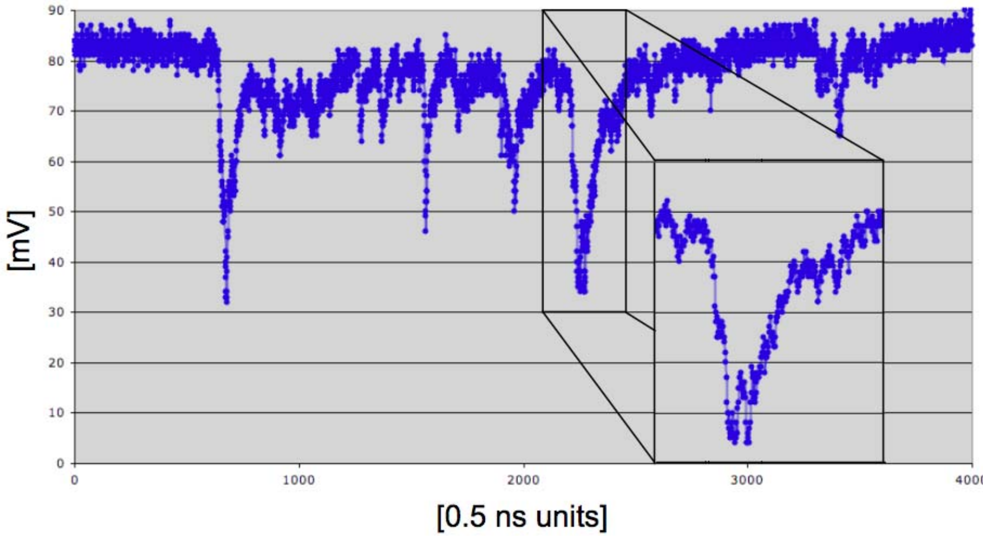
Particle identification using **dN/dx**, in principle, down to **2.5%**, as opposed to **dE/dx at 5-6%** at best.

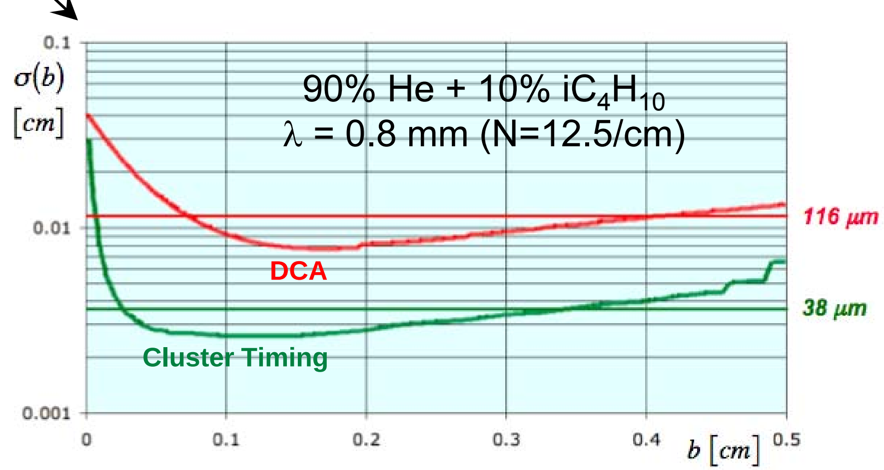
High concern about the problem of the **positive ion feedback in a TPC** causing trajectory distortions (affecting resolution) and drifting electrons recombination (affecting efficiency).

Central Tracker

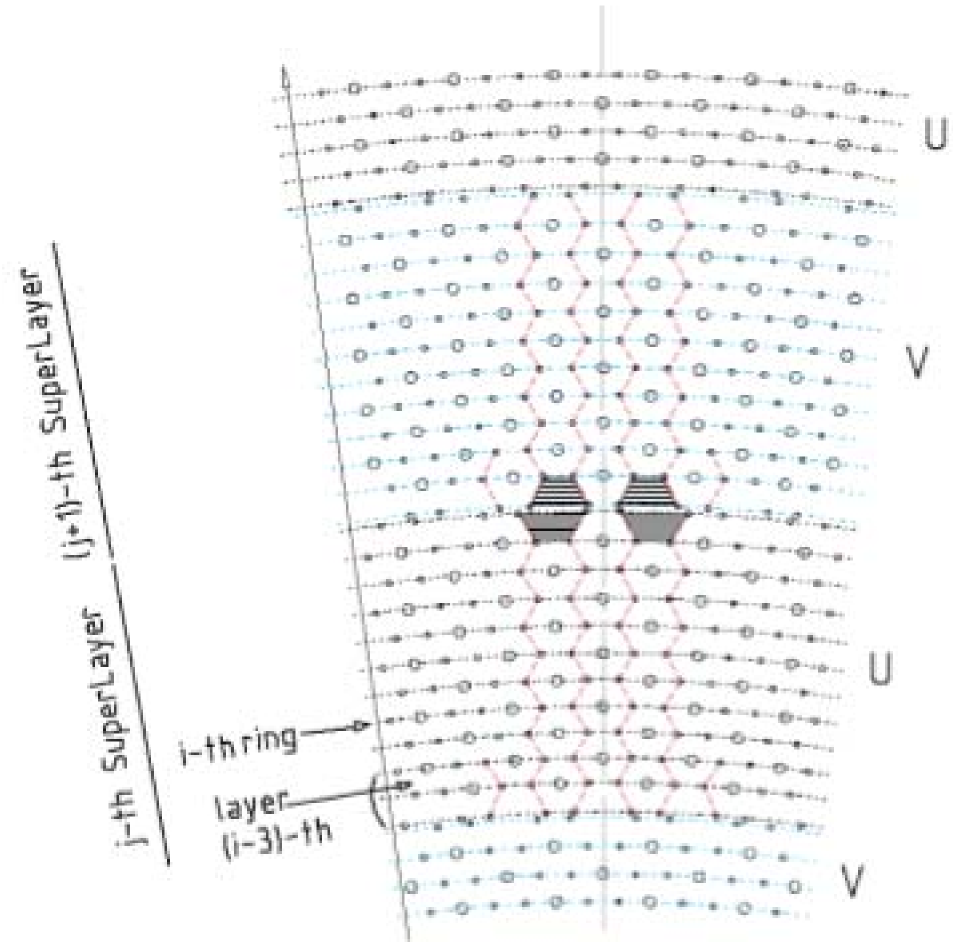
Cluster timing in drift chambers consists in recording the drift times of all individual ionization electrons collected on a sense wire and due to the passage of an ionizing track in the active gaseous medium.
This leads to spatial resolutions like







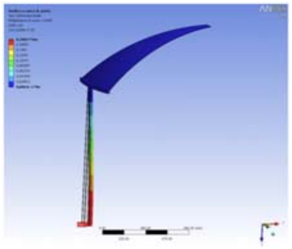
Central Tracker



General layout based on successful operation of KLOE drift chamber

R_{in} = 19 cm
R_{out} = 150 cm
R_{dome} = 242 cm

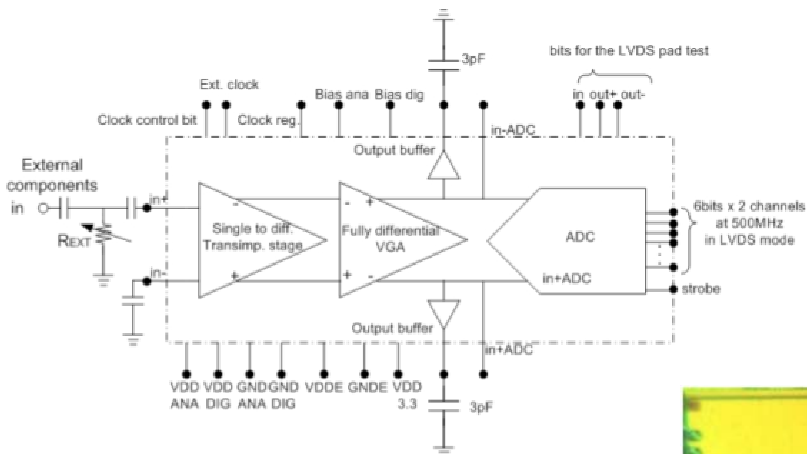
Cell size from 0.4 cm to 0.7 cm side
160 axial measurements (on average)
Stereo angles from 55 mrad to 220 mrad
sense wires = 66000 (5X KLOE)
field wires = 150000 (4X KLOE)



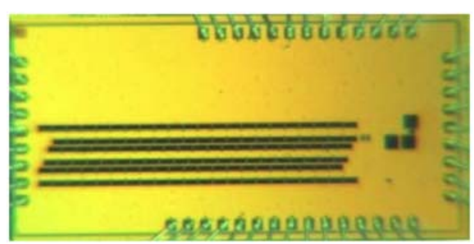
Design, structural stability, types of carbon fiber and other component materials are given in a mechanical engineering thesis, together with a strategy for the wiring procedure, taking into account the deformation of the structure while the wires are tensioned.

Central Tracker

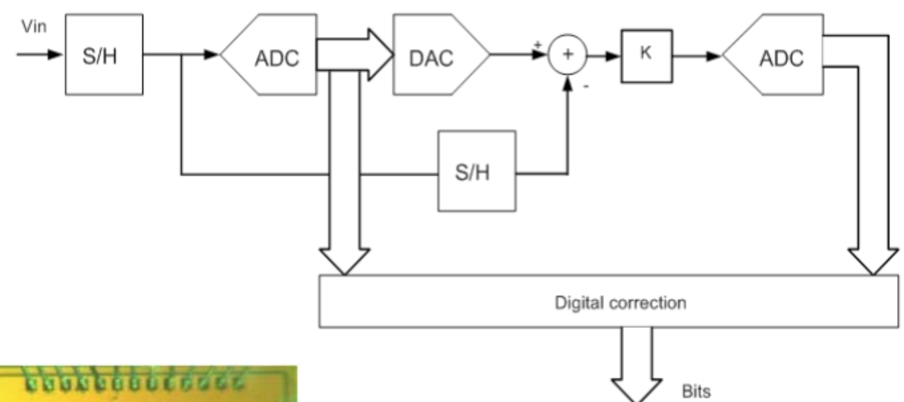
The implementation of the cluster timing technique requires a **low cost**, **high-speed**, **low-power** electronic interface able to process the drift signals. We have designed a **CMOS 0.13μm** integrated readout circuit, including a **fast preamplifier** (with a -3dB bandwidth of **700 MHz**) and **1 GSa/s-6bit ADC** to fulfill all the requirements for cluster timing. (2nd version by June 2009)



preamplifier

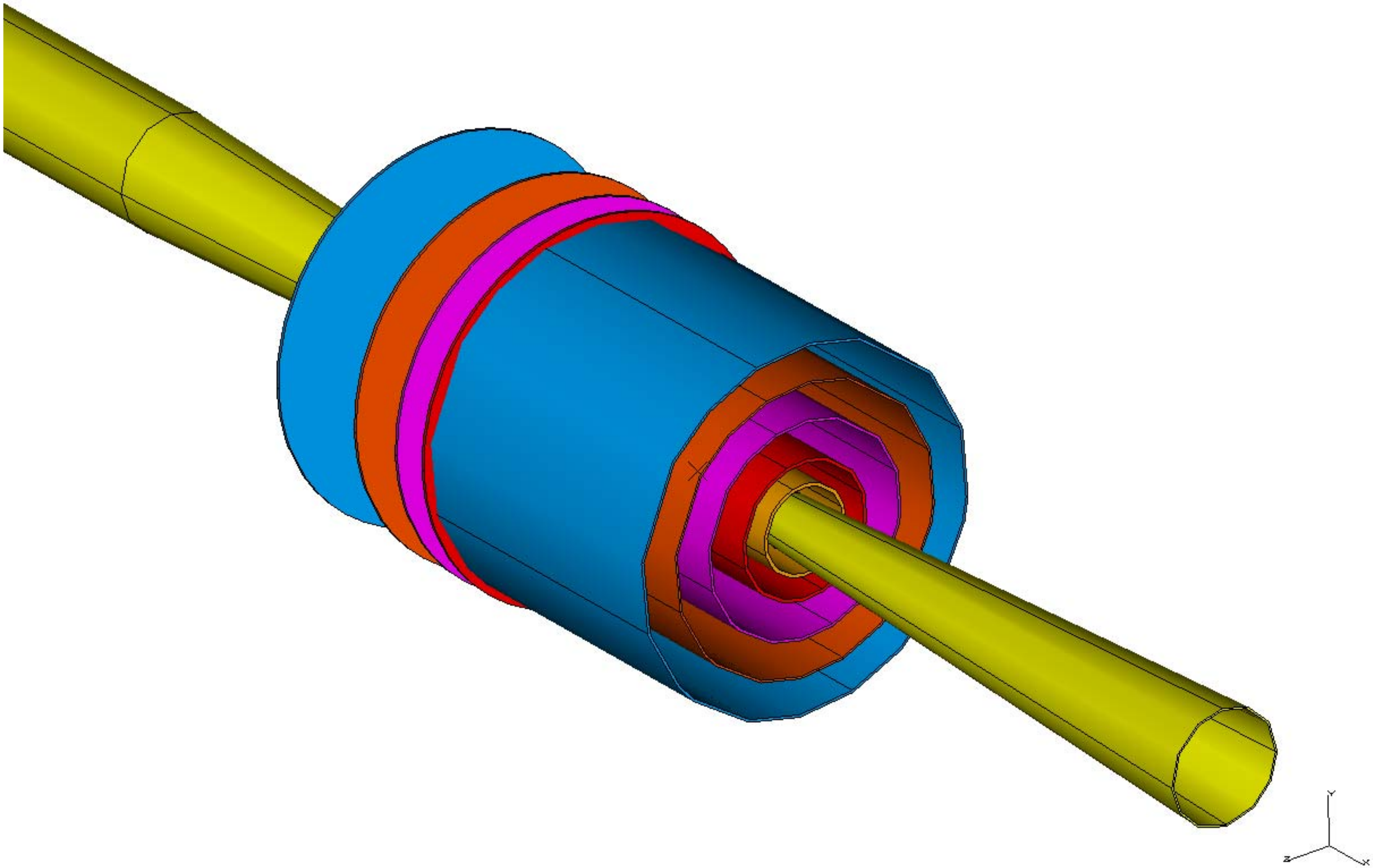


microphotography (1st version)

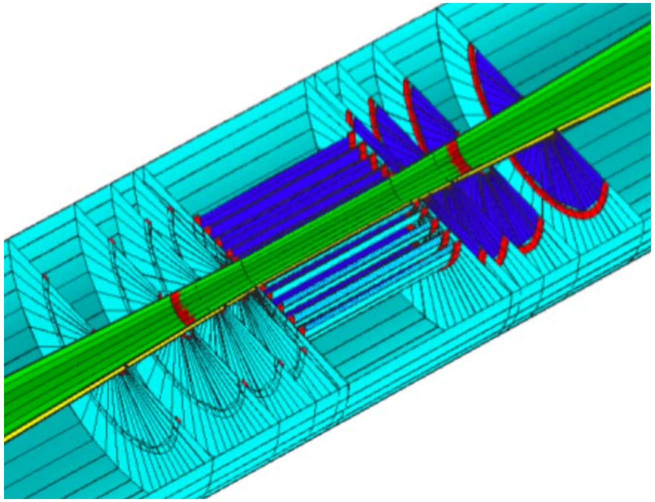


Flash ADC

Removed drift chamber



Vertex Detector



Vertex Detector:

multi Giga-pixel chamber with cylinders and disks according to SiD thin pixel design scaled up for B = 5T $\rightarrow$ 3.5T.
4th Concept is not currently working on a pixel chamber design.

VXD + Be beam pipe $\rightarrow$ 1.2% X_0

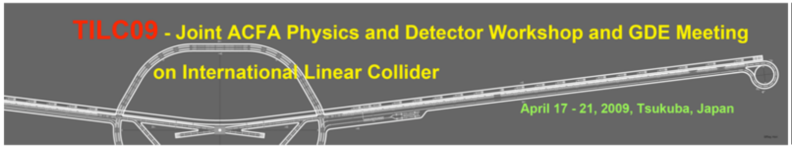
Detector Optimization

At this stage, the uncertainties on the costs of the various subsystems are much larger than any possible cost optimization, unless of drastic changes in technologies.

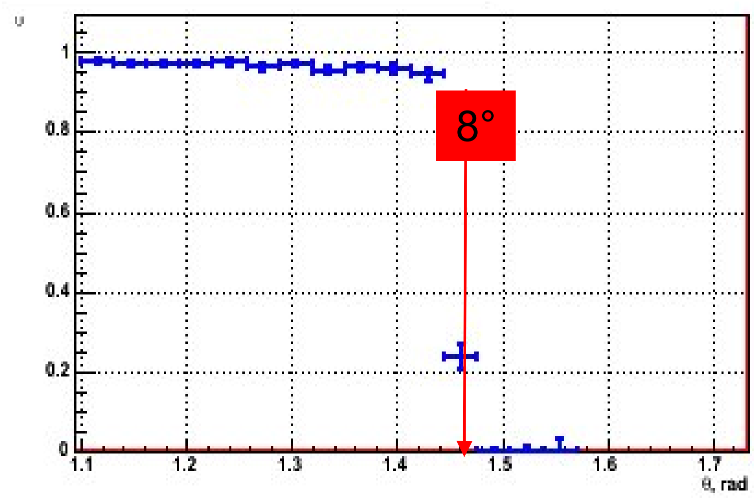
In general, the size of a detector is determined by its resolutions. We think we have achieved a good balance of resolutions in this detector design.

Electrons, muons, hadrons and jets at around 100 GeV are all measured with comparable resolutions both by the tracking systems and by the crystal and fiber calorimeters.

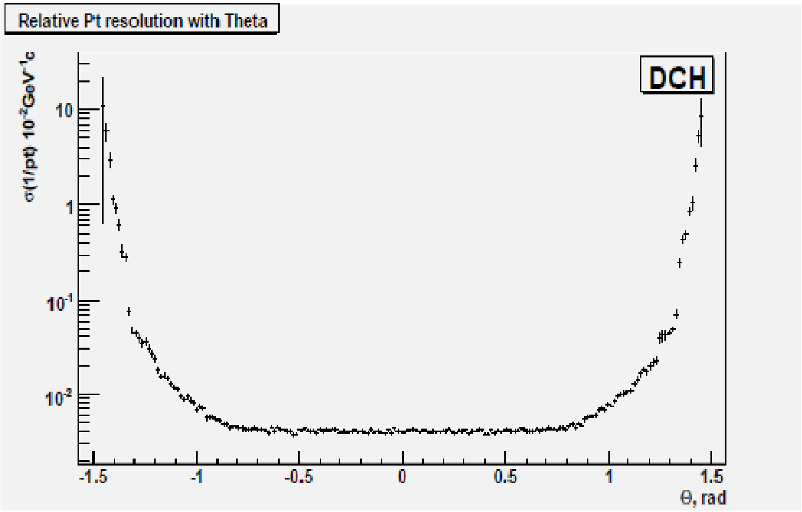
Any, even moderate, increment in the dimensions of one sub-detector to increase its performance will be made at the expenses of the other sub-detectors with a resulting imbalance in the resolutions on these fundamental partons.



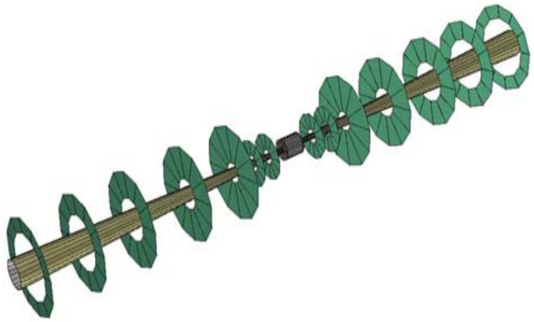
Alternative technological Options



Drift chamber efficiency vs theta



Momentum resolution vs theta



Synergy with collaborators from SILC:
introduce a set of silicon detectors inside inner cylindrical wall of drift chamber, eventually, increase inner radius of chamber

(see 4th Performance talk by C.Gatto)

Cost Estimate

Costs are in 2008 US$. Contingency reflects the uncertainty in the estimates. The total manpower divided into technical (70-75%) and engineering (25-30%).

Detector system	Total cost [M$]	contingency [M$]	manpower [person-years]
Vertex pixel	10.0	4.0	90.0
Central tracker	24.40	5.0	188.
Crystal calorimeter	99.36	20.0	120.
Fiber calorimeter	53.22	10.0	136.
Muon spectrometer	14.09	3.0	130.5
Dual solenoids	180.00	50.0	160.
Trigger/DAQ	20.00	5.0	40.0
Beam/Lumi Calors	6.00	1.5	18.0
MDI/shielding	4.00	2.0	15.0
Total	411.07	100.5	897.5

Experimental hall, including utilities, services, connections to MDI, service cranes, He systems, surface buildings, are not included in the estimate as well as offline computing and data storage.

Cost Estimate

CALORIMETERS					unit cost	pieces	$	$
HADRONIC								
	TOWER	brass	125Kg		2,75	125	344	
		sci.fibers	1.5 m		0,40	1.500	600	
		C^fibers	1.5 m		0,40	1.500	600	
								1.544
	WHEEL	azimuth	20 ton		1.544	256	395.200	
		support hardware			10.000	2	20.000	
								415.200
	BARRELL	32 + 32 wheels	1280 tons		415.200	64	26.572.800	
		outer supports			24.000	32	768.000	
		inner supports			24.000	32	768.000	
		lifting tools			30.000	4	120.000	
		mech. Kit			10.000	64	640.000	
								28.868.800
	END CAP							
		30 rings	466 tons	3726 towers	1.544	3.725	5.750.469	
		outer supports			24.000	16	384.000	
		inner supports			24.000	16	384.000	
		internal support cone			100.000	1	100.000	
		mech. Kit			8.000	32	256.000	
		sliding machanism			500.000	1	500.000	
								7.374.469
HADRONIC								
		barrell			28.868.800	1	28.868.800	
		end cap			7.374.469	2	14.748.938	
		joining fixtures			100.000	2	200.000	
		external support structure			200.000	2	400.000	
								44.217.738
STRUCTURES		brass machine			800.000	1	800.000	
		block cutting machine			600.000	1	600.000	
		assembly tables			200.000	1	200.000	
		fiber dispenser machine			200.000	1	200.000	
		fiber tools			200.000	1	200.000	
		photo-converter coupling			200.000	1	200.000	
								2.200.000
ELECTRONICS		photo-converters			120	24.000	2.880.000	
		front end chip			25	24.000	600.000	
		fADC + memory + FPGA card (16 ch each)			90	24.000	2.160.000	
		LV power supply + cables + connectors			40	24.000	960.000	
		miscellanea			200.000	1	200.000	
								6.800.000
HADRONIC								
		barrell + end caps			44.217.738	1	44.217.738	
		structures			2.200.000	1	2.200.000	
		electronics			6.800.000	1	6.800.000	
								53.217.738
ELECTROMAGNETIC								
	TOWER MODULE	BGO 2x2 blocks per tower			800	4	3.200	
		mechanical structure			100	1	100	
		photo-converter			100	4	400	
		miscellanea mech.			0	1	0	
		front end chip			20	4	80	
		fADC + memory + FPGA card (4 ch)			75	4	300	
		LV power supply + cables + connectors			15	4	60	
		miscellanea elects.			0	1	0	
								4.140
ELECTROMAGNETIC								
		24000 tower modules			4.140	24.000	99.364.140	
								99.364.140
CALORIMETERS								
		electromagnetic			99.364.140	1	99.364.140	
		hadronic			53.217.738	1	53.217.738	
								152.581.878

CENTRAL TRACKER				unit cost	pieces	$	$
COMPONENTS							
	CFRP						
		dome end plates		800.000	2	1.600.000	
		struts		30.000	12	360.000	
		rings		50.000	2	100.000	
		inner cylinder		300.000	1	300.000	
		outer panels		30.000	12	360.000	
		stiffening rings		50.000	2	100.000	
		supplementary parts		500.000	1	500.000	
							3.320.000
	MACHINING						
		dome end plates drilling		400.000	2	800.000	
		end plates gold plating		80.000	2	160.000	
		struts		18.000	12	216.000	
		rings		25.000	2	50.000	
		inner cylinder		100.000	1	100.000	
		outer panels		18.000	12	216.000	
		stiffening rings		25.000	2	50.000	
		supplementary parts for assemblying		300.000	1	300.000	
							1.892.000
	FEEDTHROUGHS						
		sense wires	gold plated Al alloy	5	180.000	900.000	
		field wires	silver plated Al alloy	2	400.000	800.000	
		guard wires	silver plated Al alloy	2	60.000	120.000	
		insertion tools and spares		10.000	4	40.000	
		crimping tools and spares		20.000	4	80.000	
		soldering tools and spares		12.000	4	48.000	
		consumables		200.000	1	200.000	
							2.188.000
	WIRES						
		20 micron W in 1000 m spools		600	500	300.000	
		80 micron Al in 1000 m spools		800	1.200	960.000	
		100 micron Al in 1000 m spools		800	150	120.000	
		motorized wire dispenser tables and spares		6.000	12	72.000	
		tensiometers for wire tension		10.000	4	40.000	
		consumables		200.000	1	200.000	
							1.692.000
	COMPONENTS						
		CFRP		3.320.000	1	3.320.000	
		Machining		1.892.000	1	1.892.000	
		Feedthroughs		2.188.000	1	2.188.000	
		Wires		1.692.000	1	1.692.000	
							9.092.000
WIRING		clean room + consumables		600.000	1	600.000	
		endplate stand (mechanics)		100.000	2	200.000	
		inner shaft and rotating system		50.000	1	50.000	
		pressure gages and recovery meas.		10.000	36	360.000	
		external wiring robots		90.000	4	360.000	
		internal wiring robots		60.000	2	120.000	
		tension control system (wire resonance)		40.000	2	80.000	
		HV test station		40.000	1	40.000	
		wiring tools		50.000	1	50.000	
							1.860.000
ELECTRONICS		HV distribution cards (10 ch each)		80	6.602	528.160	
		front end chip (66020 channels)		30	66.020	1.980.600	
		fADC + memory + FPGA card (10 ch each)		800	6.602	5.281.600	
		HV power supply + cables + connectors		400	6.602	2.640.800	
		LV power supply + cables + connectors		200	6.602	1.320.400	
		miscellanea		300.000	1	300.000	
							12.051.560
GAS SYSTEM		30 cubic meters					
		binary mixture (nonmost likely flamable)					
		alarm and security systems					
		1 full volume exchange per 2 hours max flow					
		gas quality control and monitoring					
		input at inner radius, output at outer radius					
		gas connectors and transport lines					
							1.400.000
CENTRAL TRACKER							
		Components		9.092.000	1	9.092.000	
		Wiring		1.860.000	1	1.860.000	
		Electronics		12.051.560	1	12.051.560	
		Gas system		1.400.000	1	1.400.000	
							24.403.560